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CONFERENCE IN THE MATTER OF POLLUTION OF THE SOUTH PLATTE RIVER BASIN IN THE STATE OF COLORADO. 2ND SESSION, DENVER, COLORADO, APRIL 27 AND 28, 1966. PROCEEDINGS. VOLUME III

Federal Water Pollution Control Administration
Denver, Colorado

1966

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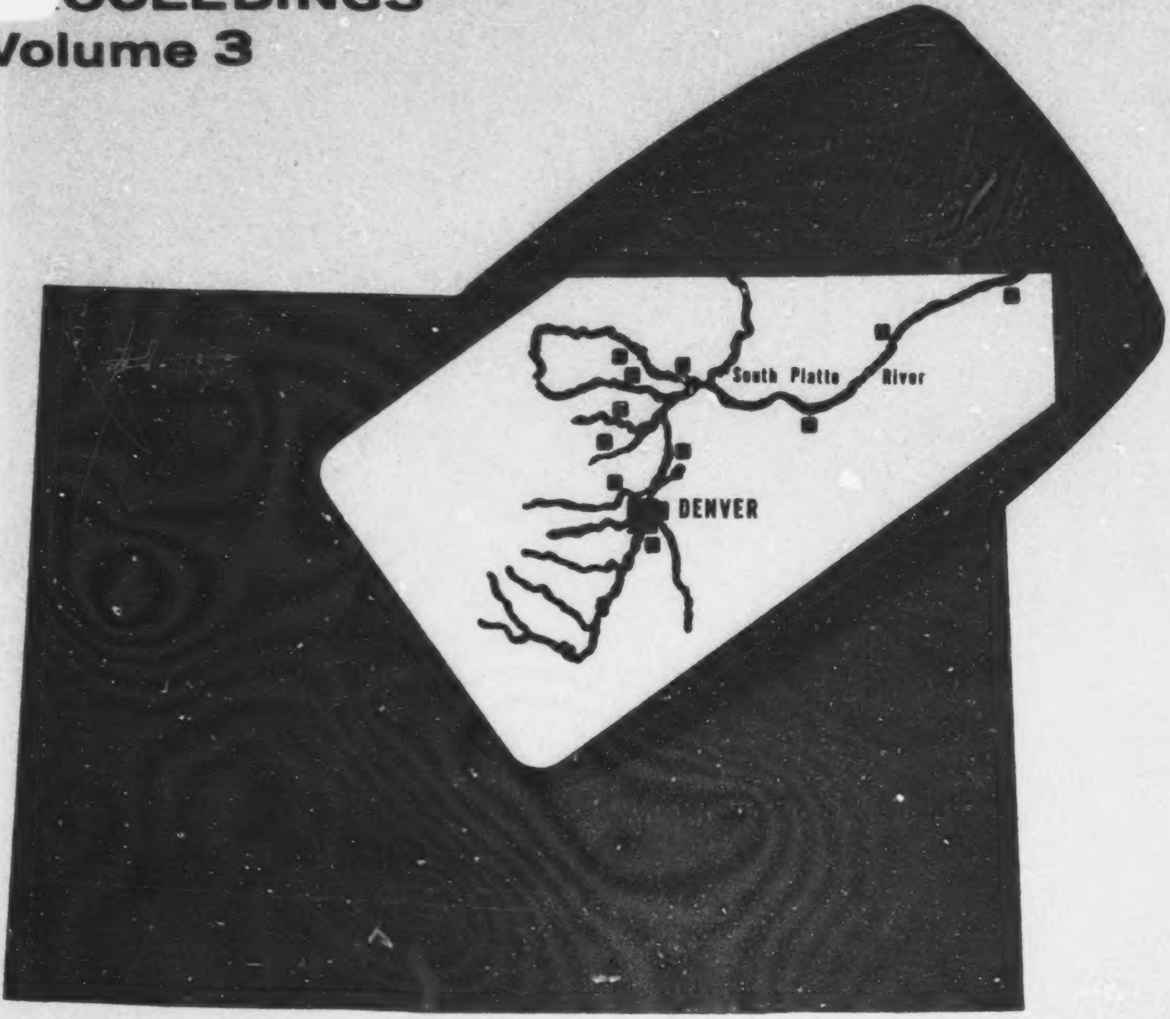
Volume 3



Conference

In the matter of Pollution of the South Platte River Basin in the State of Colorado

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SECOND SESSION
DENVER, COLORADO
April 27 & 28, 1966

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

9

INDEX

STATEMENT OF:	PAGE:
Opening Statement, M. Stein	3
L. M. Klashman	16
M. A. Bauer	22
E. V. Fitzpatrick	33
E. J. Struzeski	79
K. Monfort	111
E. J. Struzeski	153
M. A. Bauer	174
H. P. Dugan	195
R. Foster	199
R. L. Cleere	201
H. A. Feder	215
S. Johnson	221
W. R. Seaman	227
R. G. Wilson	229
T. L. Sundquist	236
D. D. Pfeifer	239
F. Rozich	241
C. R. Hampton	245
Wm. C. Kunzman	259
AFTERNOON SESSION	111

INDEX

STATEMENT OF:	PAGE:
H. L. Smith	262
J. D. Wingeart	265
F. Rozich	271
L. H. Stroud	272
F. Rozich	274
Wm. N. Gahr	275
C. Waselko	277
L. T. Jensen	282
C. D. Malchow	309
F. Rozich	316
W. C. Lackemann	319
R. K. Binkley	323
J. Helbig	328
G. J. Mullis	332
M. Rechnitz	334
F. Rozich	336
H. Lewis	340
N. Skau	346
J. J. Ryan	348
W. R. Dobratz	350
APPENDICES	368

Conference in the Matter of Pollution of the Navigable Waters of the South Platte River Basin within the State of Colorado, convened at 9:00 a.m., on Wednesday, April 27, 1966, at the Colorado State Capitol Building, Denver, Colorado.

PRESIDING:

Mr. Murray Stein, Chief, Enforcement Activities, Federal Water Pollution Control Administration, Department of Health, Education, and Welfare, Washington, D. C.

CONFEREES:

Dr. Roy L. Cleere, Director, Colorado State Department of Public Health

Mr. R. T. Eckles, Coordinator of Natural Resources, Chairman, State Water Pollution Commission

Mr. Lester Klashman, Regional Program Director, Region VIII, Water Pollution Control Administration, Department of Health, Education, and Welfare, Denver, Colorado

SIGNIFICANT VECTOR PROBLEMS
IN THE SOUTH PLATTE RIVER BASIN

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Region VIII
Denver, Colorado

March 1965

Division of Water Supply and Pollution Control
South Platte River Basin Project
Denver, Colorado
and
Communicable Disease Center
Disease Ecology Section
Greeley, Colorado

M. A. Bauer

SOUTH PLATTE RIVER BASIN PROJECT
U. S. PUBLIC HEALTH SERVICE

Background and Objectives

On July 18, 1963, the Governor of Colorado requested the Secretary of Health, Education, and Welfare to assist the State in determining sources of pollution and quality of waters of the South Platte River Basin within the State of Colorado.

The First Session of the Conference in the Matter of Pollution of the South Platte River Basin was held in Denver, Colorado, on October 29, 1963, under the provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 466g). It was established at this Conference that a study would be undertaken by facilities of the U. S. Public Health Service. Findings and recommendations from this study would lead to a program of pollution abatement to be developed jointly by the South Platte River Basin Project, Public Health Service, and the Colorado State Department of Public Health.

The long-range goals and objectives of the Project are as follows:

1. Determine the legitimate water uses and locate the sources of pollution having an adverse effect on those uses.
2. Through field investigations determine the physical, chemical, and biological responses of the river to pollution and evaluate the previously located sources of pollution with respect to the conditions in the river.
3. Compute the waste load reductions necessary to obtain desired water quality and recommend water quality control measures needed to effect the desired waste load reductions.

Organization

The South Platte River Basin Project consists of engineering and associated professional and clerical personnel. The Project headquarters offices are located in downtown Denver and the laboratory has been established at the Colorado State Department of Public Health, Denver, Colorado. The Project is administratively attached to the Water Supply and Pollution Control Program of the Public Health Service, United States Department of Health, Education, and Welfare, Region VIII, Denver, Colorado.

ACKNOWLEDGMENTS

Grateful acknoledgment is made to the following agencies for their assistance and cooperation extended in the preparation of this report:

Denver, City and County
Department of Health and Hospitals
Division of Environmental Health
Denver, Colorado

Inter-County Regional Planning Commission
Denver, Colorado

Tri-County District Health Department
Adams City, Colorado

U. S. Department of Health, Education, and Welfare
Region VIII, Public Health Service
Communical Disease Control Services
Denver, Colorado

SUMMARY AND CONCLUSIONS

Essentially the vector problems within the Basin involve mosquitoes, rats and flies. Flies occur widely throughout the Basin and transmit a wide range of enteric diseases. Certain serious diseases are transmitted by mosquitoes and rat fleas (i.e., encephalitis and plague, respectively), and are of considerable public health significance. Aside from their disease-causing potential, mosquitoes, rats and flies are responsible for substantial economic losses and require considerable expenditures for their elimination and control.

Ideal mosquito breeding grounds exist throughout the Basin. Improper irrigation practices create many seeps and standing pools of water in which mosquitoes breed readily. In addition, the many sloughs and backwaters along the river bottoms provide ideal areas for mosquito production. The presence of heavy organic pollution from sewage and industrial wastes in many of these waters enhances the environment for excessive production of those species of mosquitoes associated with the transmission of encephalitis. Encephalitis has occurred sporadically in the Basin with the most recent outbreaks of note occurring in 1957 and 1964.

Certain areas within the Basin have serious rat infestation problems. The most notable of these is the concentration of a large rat population along the banks of the South Platte River and its tributaries in the northern sector of Metropolitan Denver. Rats are actually semi-aquatic by nature and adapt readily to life along river banks, particularly where brush and trash along the banks provide good cover and harborage. In this case, an excellent food supply is readily available from the heavy load of floating organic pollution present in the South Platte River and its tributaries. The presence of this highly concentrated rat population constitutes a potential plague threat to area citizens.

Several species of biting and non-biting gnats and black flies breed extensively in the waters of the Basin. These insects cause severe human annoyance and occasionally are involved in disease transmission. The presence of organic pollution in the breeding waters creates a favorable larval environment and results in increased production of these insects. The most serious house fly problems in the Basin stem from the extensive breeding of flies in the accumulated manure piles associated with cattle feedlots and stockyards and in the garbage spread for the feeding of hogs at various hog farms. These substances all provide the type of warm, moist, organic environment required for fly larvae development. Many of these farms and feedlots are in close proximity to Basin streams.

Significant vector populations of mosquitoes, rats and flies exist in the Basin and constitute a serious public health hazard. These vectors, especially mosquitoes and rats, are directly associated with the organic pollution present in the waters of the Basin. This pollution is instrumental in creating and supporting the present high population levels of disease-carrying vectors, particularly in the Denver Metropolitan Area.

Future vector population levels will remain high as long as significant quantities of organic pollutants are discharged to the waters of the Basin. Reduction or elimination of present vector populations will best be accomplished through the abatement or elimination of the gross organic pollution now being discharged to receiving waters throughout the Basin.

INTRODUCTION

The objectives of this study were to determine the nature and extent of the significant disease vector problems within the South Platte River Basin and to evaluate the effect of water pollution on vector population levels.

The South Platte River drainage encompasses 24,300 square miles, of which 19,450 is in the State of Colorado and 2,050 and 2,800 square miles respectively in the States of Wyoming and Nebraska. The South Platte River originates on the east side of the Continental Divide in central Colorado, flows northeast across the State, and joins the North Platte River at North Platte, Nebraska. Principal tributaries of the South Platte River are Bear Creek, Cherry Creek, Clear Creek, St. Vrain Creek, Big Thompson River, Cache la Poudre River, Crow Creek, and Lodgepole Creek. A general map of the South Platte River Basin is given in Figure 1, following page 22.

Surface water resources in the Basin have been greatly overappropriated for irrigation use. In summer, very low flows occur at many points on Basin streams where agricultural diversions may use all, or nearly all, of the available streamflow.

The 1960 population of the Basin was approximately 1,210,000 persons, of which 92 percent was in the State of Colorado, and four percent each in Wyoming and

Nebraska. The population has increased at a very rapid rate. From 1940 to 1950 the population increased from 660,000 to 840,000, with an estimate for 1964 of 1,410,000. (1)

The population growth of the Denver Metropolitan Area has been particularly remarkable with an increase from 1950 to 1960 of 499,000 to 804,000, and a further rise to approximately 1,000,000 persons as of 1964. The Denver Metropolitan Area contains about 70 percent of the total Basin population and is an extremely important manufacturing and trade center for a large part of the Rocky Mountain Region. Other centers of population in the Basin as of 1964 include Boulder, 46,000; Fort Collins, 30,400; and Greeley, Colorado, 31,600; as well as Cheyenne, Wyoming, 52,000. (1)

The approach used in respect to this evaluation was to review those reports on file at the Disease Ecology Section, Communicable Disease Center, Greeley, Colorado, which dealt with the vector studies conducted by CDC and other health agencies within the Basin. Also, a mosquito survey and other field observations were made within the Denver area by South Platte River Basin Project and CDC personnel during the summer of 1964. The above information, supplemented by information of a general nature, has been used to present an overall picture of the present-day vector problems within the Basin.

GENERAL DISCUSSION

Mosquitoes

Mosquitoes are the vectors of principal public health significance in the Basin. Several species of public health and socio-economic importance are produced in large numbers in areas where environmental conditions are favorable.

Viral encephalitis, commonly known as sleeping sickness or brain fever, is now the most important mosquito-borne disease in the United States and in the South Platte River Basin. This should not be confused with the dread African sleeping sickness (Trypanosomiasis) which is transmitted by the tsetse fly and caused by a microscopic parasitic protozoan.

The reservoir for viral encephalitis is thought to be the blood of wild birds and domestic poultry. Mosquitoes obtain the virus by feeding on infected birds and transmit it to horses and humans while obtaining subsequent blood meals, as shown in Figures 2a and 2b.

(Figures 2a and 2b are as follows:)

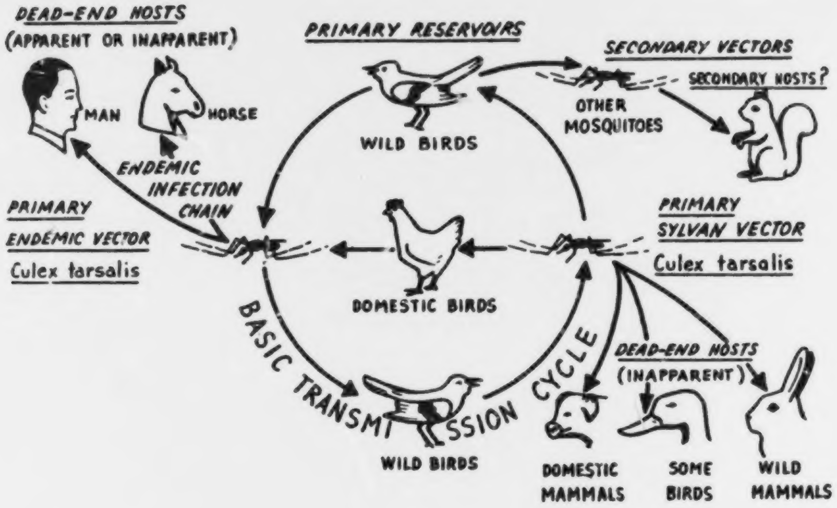

DEAD-END HOSTS
(APPARENT OR INAPPARENT)
MAN
HORSE
PRIMARY RESERVOIRS
WILD BIRDS
SECONDARY VECTORS
OTHER MOSQUITOES
SECONDARY HOSTS?
ENDEMIC INFECTION CHAIN
PRIMARY ENDEMIC VECTOR
Culex tarsalis
DOMESTIC BIRDS
PRIMARY SYLVAN VECTOR
Culex tarsalis
BASIC TRANSMISSION CYCLE
DEAD-END HOSTS
(INAPPARENT)
WILD BIRDS
DOMESTIC MAMMALS
SOME BIRDS
WILD MAMMALS

Figure 2a: Summer infection chains for western equine encephalitis. (The chains for rural St. Louis encephalitis are similar except that horses are inapparent rather than apparent hosts.) Hess and Holden, 1958.

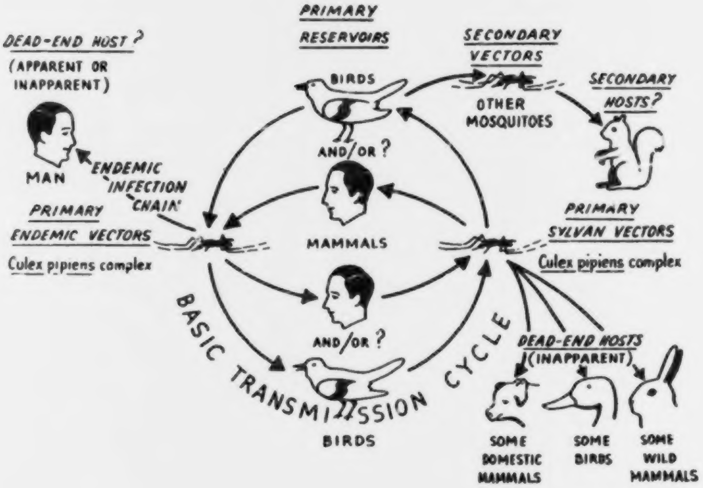

PRIMARY RESERVOIRS
DEAD-END HOST?
(APPARENT OR INAPPARENT)
BIRDS
SECONDARY VECTORS
OTHER MOSQUITOES
SECONDARY HOSTS?
AND/OR ?
MAN
ENDEMIC INFECTION CHAIN
PRIMARY ENDEMIC VECTORS
Culex pipiens complex
MAMMALS
PRIMARY SYLVAN VECTORS
Culex pipiens complex
AND/OR ?
BASIC TRANSMISSION CYCLE
DEAD-END HOSTS
(INAPPARENT)
BIRDS
SOME DOMESTIC MAMMALS
SOME BIRDS
SOME WILD MAMMALS

Figure 2b: Summer infection chains for urban St. Louis encephalitis (chains for rural SLE are similar to those for WEE). Hess and Holden, 1958.

M. A. Bauer

There are no effective chemotherapeutic measures for the prevention of or treatment of human cases and some individuals, particularly children who recover from the disease, often suffer permanent mental disability.

Three types of vital encephalitis are commonly recognized in the United States: Eastern Equine Encephalitis (EEE), Western Equine Encephalities (WEE), and St. Louis Encephalitis (SLE). The geographical distribution of the three virus types is given in Figure 3.

(Figure 3 is as follows:)

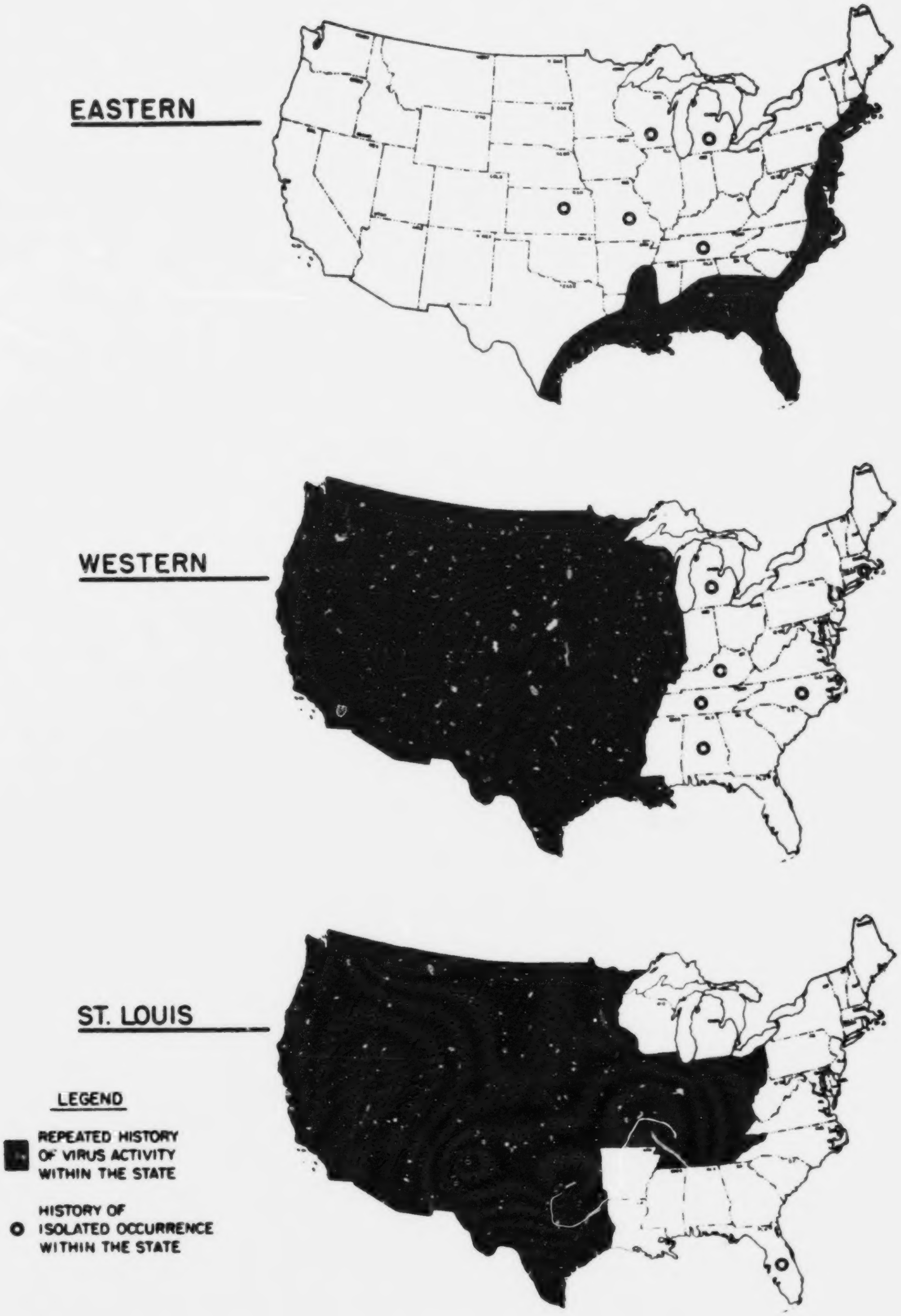

EASTERN
WESTERN
ST. LOUIS
LEGEND
REPEATED HISTORY OF VIRUS ACTIVITY WITHIN THE STATE
HISTORY OF ISOLATED OCCURRENCE WITHIN THE STATE

Figure 3. The geographical distribution of the arthropod-borne encephalitides in the United States. Total virus activity in man and in animals. Hess and Holden, 1958.

Both EEE and WEE produce clinical disease in man and horse alike, while SLE produces clinical disease in man only. Of the three virus strains, WEE and SLE are endemic to the Basin. Encephalitis has occurred in horses throughout the Basin for the period of record dating back to 1939. Human cases have occurred sporadically and intermittently with the more recent outbreak of note occurring in 1957, when over 100 cases were reported, and in 1964, when 30 were reported, including three fatalities.

Members of the genus Culex are the most significant mosquitoes in the transmission of encephalitis in the Basin. Entomological investigations have shown that these mosquitoes occur in great numbers throughout the Basin and have considerable impact as a nuisance problem aside from the disease-carrying potential.

Culex tarsalis is the single most important vector of encephalitis for man and horses in the Basin. The mosquito feeds readily on birds, horses, and man, with some preference indicated for birds. An interesting explanation for the C. tarsalis-bird association is given as follows:

Many birds nest in trees, going to roost about dusk, which coincides with the most active feeding period for C. tarsalis. The foliage of the trees gives off an excess of carbon dioxide at night, when photosynthesis has ceased. C. tarsalis is attracted by carbon dioxide and is brought into the sphere of the roosting birds at the time when it is most active in seeking a blood meal. (2) Since birds also act as the reservoir for the encephalitis virus, all the elements for transmission of the disease are brought together in time and space.

C. tarsalis larvae develop in a wide variety of aquatic environments, and are frequently found in waste water associated with improper irrigation practices. They also breed in artificial containers and structures including cesspools. Waters containing large quantities of organic matter from human wastes are often preferred. Dispersion studies have shown that adult C. tarsalis will fly as far as ten miles, but the majority of individuals probably remain within one mile of the original larval habitat. (3)

Culex pipiens and Culex quinquefasciatus are of importance in the transmission of urban SLE in human populations, particularly in the Midwest. Within the Basin, C. pipiens and Culiseta inornata are considered to be of particular significance in the transmission cycle of encephalitis among bird and wild mammal hosts, respectively. C. pipiens and C. quinquefastiatus breed profusely in practically all types of artificial containers and in polluted ground pools, cesspools, open septic tanks, and effluent drains from sewage treatment plants. (2) C. pipiens in particular is often associated with grossly polluted water and will breed readily even in undiluted sewage.

The presence of ideal breeding sites and mosquito problem areas within the Basin is well documented by various reports on file at CDC, Greeley, and by field observations by CDC and South Platte River Basin Project personnel. In addition, field studies conducted during the summer of 1964 indicate extensive production of C. tarsalis and C. pipiens in the sewage-laden waters northeast of **Denver.**

The mosquito vectors of encephalitis would undoubtedly be present to some degree in the Basin even if no water pollution were present. However, the presence of organic pollution from sewage and industrial wastes in certain of the waters, particularly the South Platte River, leads to increased production of these vector mosquitoes. Not only is the water enriched in terms of larval food supply, but existing predator populations are generally intolerant of this pollution. The resulting increase in adult mosquito populations often creates increased competition for the available supply of blood meals.

The mosquitoes then range more freely in search of food, thus increasing the possibility of contacting a bird or mammal infected with encephalitis virus and subsequently transmitting the disease to man.

A close scrutiny of the Basin topography helps to explain why encephalitis is common within the South Platte River Basin. A great portion of the area consists of rolling plains cut by meandering streams which create uncounted backwaters and sloughs along their bottoms. As previously explained, the presence of organic pollution in many of these waters enhances the production of vector mosquitoes. Climate and topography limit the only significant concentrations of trees in the Basin to the stream bottom land. As birds generally require trees for roosting and nesting, a large avian population is concentrated along the stream bottoms. These conditions establish an ideal environment for the perpetuation of both host and vector populations.

Several species of the vicious-biting Aedes mosquito occur in the Basin area. These species are produced in great numbers in temporary surface pools associated with irrigation and in ponds or reservoirs having shallow, vegetated areas subject to fluctuating water levels. Overflow pools along streams also provide favorable larval habitats for these highly pestiferous mosquitoes. Concentrations of these mosquitoes may create public health problems by interfering with the normal outdoor activities of both children and adults during the summer months. Children frequently require medical attention and even hospitalization for treatment of secondary infections and allergic reactions from mosquito bites. In addition to their public health importance, large numbers of biting mosquitoes also cause severe economic losses by reducing the efficiency of agricultural and industrial workers; by reducing the vitality of farm animals and thereby lowering meat and dairy production; by interfering with outdoor recreation and entertainment; and by lowering real estate values. In the form of more tangible losses, considerable expenditures are made each year by municipalities and individuals for chemical controls and screening to provide partial protection from mosquitoes.

Domestic Rats

While the South Platte River Basin provides a suitable environment for several wild rodent species, the rodent of greatest public health significance is Rattus norvegicus, the Norway rat. Beacuse of its strict dependence on man, this rodent, although essentially wild in nature, has come to be known as the domestic rat. Domestic rats are reservoirs or vectors of several diseases, among which are murine typhus fever, plague, salmonellosis, hemorrhagic jaundice or Weil's Disease, rat-bite fever, and trichinosis. (4) Of these, plague, which is endemic to the Basin, is of greatest significance to this area because of the nearly always fatal nature of the disease and the public health controls required when outbreaks occur in local rodent populations.

Plague, the "Black Death" which once was responsible for millions of deaths in Europe, Asia and Africa, and which has occurred in the coastal cities of the United States, is an acute infection running a rapid, severe course. There have been no serious outbreaks in the United States since 1924, although five cases have occurred in the Western United States since 1956, three terminating fatally. (5)

A plague reservoir exists in the blood of many of the wild rodents of the Western United States. The disease may be transmitted from wild rodent to domestic rat to man by the bit of parasitic fleas associated with these rodents. The disease is usually fatal to the rodents and fleas as well as man. Contact between rats and other rodents most frequently occurs in the area of a common food supply such as an open dump, or along waterways, particularly those polluted with organic solids. During such contact the parasitic fleas often change hosts, thereby transmitting the disease from rodent to rodent.

It is generally accepted that rats will readily infest such areas as open dumps, produce markets, farms, and stockyards, etc. Rats will just as readily infest the banks of a stream if the stream is carrying a heavy load of organic solids which will serve as a food supply. Rats require water daily and if, as in the case of the most polluted streams, they can obtain both food and water from the same source, they are more than willing. They can usually find excellent cover and harborage among the jumble of rock and brush found along most stream banks. In essence, the stream is furnishing the rats with three of the basic requirements for life -- water, food and shelter.

The fact that rats are semi-aquatic by nature and will readily "swim for their supper" is well documented by the following passage from a report by Cottam: (6)

> "An example of the Norway rat's adaptability was recently brought to my attention at the U. S. Fish Hatchery Station at Leetown, West Virginia. Despite the fact that several buildings and food

"storage bins are kept reasonably free of rats from 50 to 200 yards distant, a surprisingly large colony was found living in earthen banks adjacent to the fish ponds and stream courses where concentrations of fish are kept. The spawn, fingerlings, and adult fish -- primarily of species or varieties of trout and bass -- are fed horse meat daily as well as other prepared foods that are equally acceptable to the rat colony. Undoubtedly bits of food accidentally dropped on the bank in feeding operations accustom the rats to that type of diet. It is obvious that an inadequate food supply occurs on the land, and the rats have learned to obtain it from the water. In their competition for food, the young and small fish at all hatcheries concentrate in enormous numbers when food is thrown into the water. Consequently, food is available for a very short period only. The rats as well as the fish have learned this. Therefore, at this hatchery these normally nocturnal rats have synchronized their feeding time to correspond with the feeding of the fish. When food is thrown into the water, the rats have no hesitancy in competing for it.

"They swim well and rapidly. After the food in the water is consumed, they then seek tidbits inadvertently dropped on the bank.

"Apparently low temperature is no serious deterrent to the rat's aquatic activity. On the day of my visit, December 10, 1947, the temperature was considerably below freezing, and an unpleasant sleet and snow storm was in progress; even so, a dozen rats were observed in the water, and part of their runway extended through small areas of the stream. While omnivorous rats avidly consume all kinds of fish food, it was a surprise to find that they are not at all averse to preying on young fish. On a number of occasions the rats have been observed catching the fingerling fish and taking them into their ditchbank runways or burrows."

Identical observations have been made at the White Trout farm at Paradise, Utah, by personnel of the Logan Field Station, CDC, Logan, Utah.

Unfortunately, the overall rat problem throughout the South Platte Basin is not well documented. Problem areas have been reported in the vicinity of Boulder, Longmont, Fort Morgan, and Brush, as well as Denver.

Current information is available on the Denver area and there is no question as to the problem itself or as to the association of rats with pollution in the South Platte River. Rat infestation is extremely heavy along the South Platte River and the Burlington-O'Brian Canal in the Northern Metropolitan Area. A rat eradication program conducted by the City and County of Denver during 1963 in this area has done much to improve the situation. However, a significant rat population still remains, particularly in adjacent Adams County. The problem is further compounded by the easy paths of migration available to the rats for reaching the heart of the city itself. Should plague appear in the rat population along the river, it might then be easily and rapidly spread throughout the Metropolitan Area. Although Denver is the only area to be documented by current observation, it is also the site of the greatest population concentration within the Basin. Furthermore, on the basis of the published literature available and observations by CDC, Greeley and the Denver City and County Health Department, one can logically expect to find medium to heavy rat infestation along the banks of the Basin's streams wherever widespread organic pollution exists.

Flies and Miscellaneous Vectors

While several species of flies are present within the Basin, including some biting flies, the one of greatest public health significance is the common house fly, Musca domestica. The house fly is important because of its ability to transmit disease-causing organisms. Flies carry these organisms in five ways: 1) on their mouth parts; 2) in their vomitus; 3) on their leg and body hairs; 4) on the sticky pads of their feet; and 5) through the intestinal tract by means of fly feces. Diseases transmitted in such manner include typhoid, paratyphoid, cholera, bacillary dysentery, infantile diarrhea, amoebic dysentery, pinworm, roundworm, whipworm, hookworm, tapeworm, anthrax, and tularemia. (7)

The life cycle of the house fly begins with the egg and goes progressively through three larval stages to the pupae and finally to the adult. In rural areas the most common breeding medium is manure, although almost any warm, moist, organic material is used. Unprotected garbage is usually the source of most house fly problems in urban areas. Within the Basin a serious house fly problem does exist in the manure piles adjacent to many of the cattle feedlots and at hog farms where garbage is fed to the hogs. Many of these feedlots and hog farms are closely associated with Basin streams. House fly breeding is also associated with many areas along the Basin stream bottoms where the soil is heavily contaminated with sewage and industrial wastes carried by the streams. In the Denver area, very extensive house fly breeding occurs in the sludge-drying beds at the Denver Northside Sewage Treatment Plant.

Several groups of insects may be produced in sufficient numbers in aquatic habitats to create public health and economic problems. Deer flies and horse flies (Tabanidae) are produced along the margins of impoundments and in marshy seeps. These insects are vicious biters of both man and livestock and are sometimes involved in the transmission of diseases such as tularemia and anthrax. Some species of small gnats (no-see-ums) of the family Heleidae (= Ceratopogonidae) are also vicious biters and often cause severe reactions and vesicular lesions. In certain areas, black flies (Simulidae) plague both men and livestock with their irritating and painful bites and large swarms of these flies can kill an animal rapidly. (6) The small, non-biting midges (Tendipedidae) and the phantom midges (Chaoborinae) are another group of pestiferous insects which may be produced in both flowing and impounded waters. These insects are attracted to lights in tremendous numbers and may cause severe human annoyance.

Thriving populations of the above groups of gnats, black flies and midges are produced in moderately polluted water where they feed on suspended microscopic organics. Waters enriched by organic pollution may produce excessive algal mats which support abundant populations of many genera.

One family of flies, Syrphidae, variously known as Hover, Flower, and Bee flies, breeds in sewage and is the adult form of the rat-tailed maggot. Such flies are primarily a nuisance organism, but members of the genera Tubifera and Helophilus may cause human intestinal myiasis. (7)

Terrestial arthropods of public health significance include ticks, mites, and fleas. These are often vectors of several human diseases, including Rocky Mountain spotted fever, Colorado tick fever, tularemia, relapsing fever, tick paralysis, typhus, typhoid, and bacillary dysentery. In addition, the bites of these arthropods cause considerable irritation, discomfort and annoyance. Little association is known between these vectors and water pollution, except as they occur as parasitic forms on rats associated with pollution.

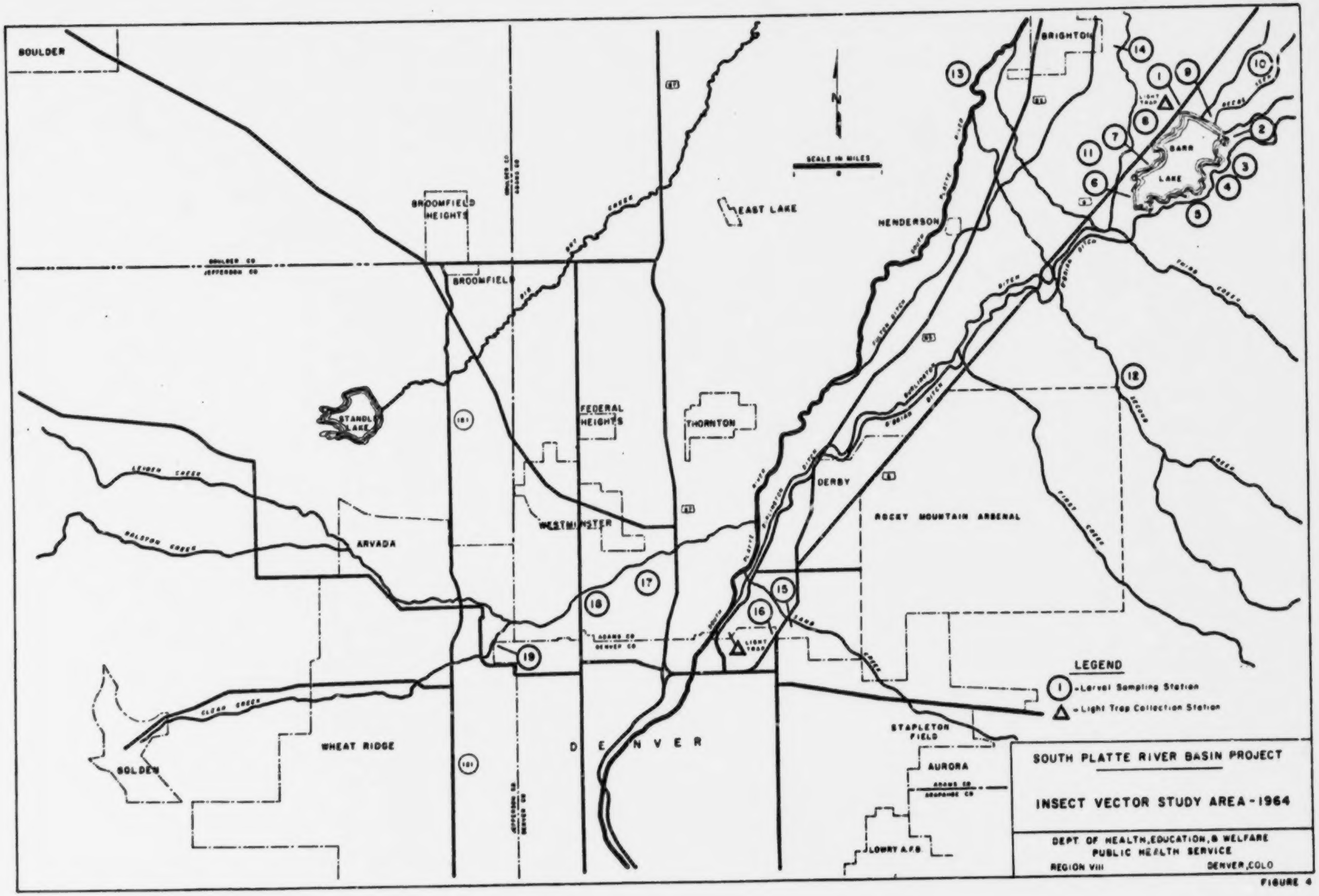
M. A. Bauer

FIELD INVESTIGATIONS - 1964

Mosquito Production in the North Denver-Barr Lake Area During the 1964 Season

A field study was conducted during the summer of 1964 to determine what species of mosquitoes, if any, were breeding in the sewage-laden surface waters northeast of Denver. A map of the study area is given in Figure 4.

(Figure 4 is as follows:)


BOULDER
BROOMFIELD HEIGHTS
BOULDER CO
JEFFERSON CO
BROOMFIELD
STANDLEY LAKE
LEYDEN CREEK
RALSTON CREEK
ARVADA
WHEAT RIDGE
GOLDEN
CLEAR CREEK
FEDERAL HEIGHTS
WESTMINSTER
THORNTON
EAST LAKE
HENDERSON
BRIGHTON
SCALE IN MILES
N
SOUTH PLATTE RIVER
FULTON DITCH
BURLINGTON DITCH
O'BRIAN DITCH
DERBY
ROCKY MOUNTAIN ARSENAL
FIRST CREEK
SECOND CREEK
THIRD CREEK
BEEBE SEEP
BARR LAKE
LIGHT TRAP
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
ADAMS CO
DENVER CO
JEFFERSON CO
DENVER CO
SAND CREEK
D E N V E R
STAPLETON FIELD
AURORA
ADAMS CO
ARAPAHOE CO
LOWRY A.F.B.
LEGEND
1 - Larval Sampling Station
△ - Light Trap Collection Station
85
6
87
121

SOUTH PLATTE RIVER BASIN PROJECT

INSECT VECTOR STUDY AREA - 1964

DEPT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLO

FIGURE 4

Fourteen larval sampling stations were selected in the Barr Lake area. Stations 1 through 7 were situated on the lake itself. The remaining seven stations were situated in a four-mile radius from the lake. All sampling was done in polluted water except for Station 12, which was fresh water seepage.

Five larval sampling stations, numbers 15-19, were set up in North Denver, principally at seepage areas along Sand Creek and Clear Creek. These two tributaries of the South Platte River are both heavily loaded with organic pollution from sewage and industrial wastes.

Larvae were collected from their natural habitat with a one-pint dipper. They were then placed in water-tight containers and taken to the CDC laboratory at Greeley where they were killed, identified, recorded and preserved.

A New Jersey type light trap was set up and operated at both the North Denver and Barr Lake areas. Each trap was equipped with a killing jar partially filled with potassium cyanide pellets, which killed the adults shortly after collection. Specimens from the traps were sorted, identified, and recorded at CDC, Greeley.

Larval collection stations were sampled at weekly intervals from May through mid-August and then at bi-weekly intervals through September 4. Light trap collections were made twice weekly at the two stations through mid-August and then at weekly intervals through September 4.

The species of mosquito larvae collected during each month and the percentage composition of each species are shown in Table I.

(Table I is as follows:)

TABLE I

Mosquito Larvae Collections

1964 Month	Type of Habitat	No. of Speci-mens	Aedes dorsalis	Aedes vexans	Culex pipiens	Culex tarsalis	Culiseta inornata
May							
	Borrow Area	45	19	0	0	14	12
	Seepage	38	0	32	0	0	6
	Totals	83	19-23%	32-39%	0	14-17%	18-21%
June							
	Borrow Area	41	4	1	0	34	2
	Reservoir	78	53	2	0	20	3
	Seepage	113	3	25	1	31	53
	Lake Shore	1	0	0	0	1	0
	Marsh	4	0	0	0	4	0
	Fresh Seepage	13	13				
	Totals	250	73-29%	28-11%	1-1%	90-36%	58-23%
July							
	Borrow Area	111	0	0	5	106	0
	Reservoir	76	0	0	0	69	7
	Seepage	143	0	0	0	110	33
	Marsh	19	4	2	0	13	0
	Lake Shore	40	0	0	0	40	0
	Fresh Seepage	38	29	0	0	9	0
	Totals	427	33- 8%	2-<1%	5-1%	347-81%	40- 9%
August							
	Borrow Area	74	0	0	4	70	0
	Reservoir	35	0	7	0	28	0
	Seepage	50	0	0	0	30	20
	Lake Shore	12	0	0	0	12	0
	Fresh Seepage	11	11	0	0	0	0
	Totals	182	11- 6%	7- 4%	4-2%	140-77%	20-11%
September							
	Borrow Area	51	0	0	24	26	1
	Totals	51	0	0	24-47%	26-51%	1- 2%
	Grand Totals	993	136-14%	69- 7%	34-3%	617-62%	137-14%

A total of 993 larvae, representing five species of mosquitoes, was collected from the representative mosquito-producing habitats during the study. Aedes vexans and Aedes dorsalis were the dominant species during the month of May, comprising 61 percent of the specimens collected. Culiseta inornata and Culex tarsalis comprised 21 percent and 17 percent of the specimens, respectively.

From June through the remainder of the study, C. tarsalis, C. pipiens and C. inornata comprised 83 percent of the total mosquito production in the study area. C. tarsalis and C. pipiens are both primary vectors in the transmission of viral encephalitis to humans, while C. inornata is a suspected vector in the transmission of the disease to animals.

On the basis of larval collections in the study area, over 93 percent of the total mosquito production recorded occurred in waters associated with heavy organic pollution. While this figure corresponds directly with the percentage of sampling stations located in polluted water, it does indicate the willingness of mosquitoes to breed in these waters. Moreover, members of the genera Culex and Culiseta, which comprised over 80 percent of this production, are the primary vectors of viral encephalitis. Such high production of these vector mosquitoes constitutes a definite public health hazard, particularly in view of the large resident human population concentrated adjacent to the mosquito-producing area. It is significant to note that 83 percent of the mosquito production occurring in the clean water sampling point was of the genus Aedes. The Aedes mosquito has considerable nuisance impact, but is regarded as having little or no importance as a vector of viral encephalitis.

Light trap collections of adult mosquitoes, as shown in Table II, indicate that A. dorsalis was the predominant species for the months of May and June. From July through the end of the study, C. tarsalis and C. pipiens became dominant, with C. pipiens of particular significance in September. It was also noted that C. pipiens were more prominent in the North Denver area than they were at Barr Lake.

Future production of vector mosquitoes in the sewage-laden waters northeast of Denver will remain at a high level so long as the present levels of pollution persist. These vector populations can best be reduced through the abatement or elimination of gross pollution now present in these waters.

(Table II is as follows:)

TABLE II

Mosquito Light Trap Collections

1964 Month	Type of Habitat	No. of Speci-mens	Aedes dorsalis	Aedes nigro-maculis	Aedes vexans	Culex pipiens	Culex tarsalis	Culiseta inornata
May								
	Barr Lake	11	5	0	0	0	2	4
	Denver	0						
	Totals	11	5-45%	0	0	0	2-18%	4-37%
June								
	Barr Lake	16	5	0	0	0	6	5
	Denver	3	2	0	1	0	0	0
	Totals	19	7-37%	0	1-5%	0	6-32%	5-26%
July								
	Barr Lake	385	2	0	7	9	346	21
	Denver	53	1	2	2	31	15	2
	Totals	438	3-<1%	2-<1%	9- 2%	40-9%	361-83%	23- 5%
August								
	Barr Lake	264	6	0	61	38	153	6
	Denver	164	2	0	4	141	17	0
	Totals	428	8- 2%	0	65-15%	179-42%	170-40%	6- 1%
September (One collection)								
	Barr Lake	11	2	0	4	1	4	0
	Denver	23	0	0	0	21	2	0
	Totals	34	2- 5%	0	4-12%	22-65%	6-18%	0
	Grand Totals	930	25- 2%	2-<1%	79- 8%	241-26%	545-59%	38- 4%

M. A. Bauer

Observations of Rat Populations in the Denver Area

On April 2, 1964, in conjunction with the Denver City and County Health Department, a survey was made to ascertain the extent of the rat problem in Denver, particularly along the waterways.

The area along the South Platte River from 46th Avenue north to the city limits has long been the focus of serious rat infestation in Denver. As a result of a plague scare in 1963, the Denver City and County Health Department conducted an extensive cleanup campaign along the South Platte River in this area. Using county prisoner help, the river banks were cleared of the trash and dense brush which previously had given the rats excellent cover and protection. In conjunction with this program, an extensive poison bait campaign was waged and still goes on today. The results have been very rewarding. Where there were once literally thousands of rats thriving along this section of the river, there now remains but a trace of the former population. Unfortunately, just across the city line in Adams County the stream and banks remain in poor condition, as shown by Figure 5, and continue to support a thriving rat population.

The survey included a visual inspection of the cleared area. With the brush and trash now gone, it could be seen that the banks were literally honeycombed with old rat burrows and runways. One area in particular presented a very desirable habitat for the rats. About 300 yards upstream from the point where the main trunk sewer to the Denver Northside Treatment Plant crosses the South Platte River, there is an outfall from a storm sewer draining the Denver Union Stockyard area. At this point a delta composed of feed corn washed from the stockyards has developed in the South Platte River, with an accumulation of corn on the order of six feet deep. This excellent food supply for the rats, along with the good shoreline harborage once made this area extremely attractive for the rats, and still supports a reduced rat population. These conditions are illustrated by Figures 6 and 7.

The problem upstream from the Denver Northside Plant is further compounded by the juncture with the South Platte of many storm sewers draining downtown Denver. When dry, these sewers offer excellent paths of migration for the rats into the heart of the city. Another possible path for the rats would be progressive migration from the stockyard area through the rail yards into the fruit and vegetable wholesale houses and finally into the city proper.

Denver Northside Sewage Treatment Plant at the junction of York Street and the South Platte River. In this area the river banks are choked with brush and debris providing ideal harborage for the rats. The stream at this point was loaded with scum, offal, and other floating organic matter, providing an excellent food supply for the rats. In essence, the rats have only to come and take their meal from the river. The poor situation is further compounded at this location by a diversion dam across the river. The river is obstructed by a jumbled mass of rock, broken concrete and debris protruding above the water as shown in Figure 8. Not only does this dam offer excellent rat harborage, but it acts as a huge strainer which traps and retains organic solids floating in the river, thus providing a ready food supply for the rats. Rats were actually observed here scurrying about in broad daylight.

More rat infestation was observed in south Adams County in the vicinity of Clear Creek and Federal Boulevard, where the City of Denver operates a modified sanitary landfill dump. One face of the dump fronts along Clear Creek, affording excellent harborage for rats, as shown in Figure 9. The stream also contains a considerable amount of organic pollution from sewage and industrial wastes, offering a ready food supply to the rats. Additionally, the marshy area surrounding the dump appears to be an excellent mosquito breeding ground. These waters are likely polluted with seepage from the dump and would offer an attractive environment for the breeding of C. tarsalis and C. pipiens in particular.

A privately-owned dump, shown in Figure 10, was observed along Sand Creek in the vicinity of the Jorgensen hog farms. Wastes from the hog farms, including an occasional dead hog, are dumped here, affording a good food supply for rats.

The rat problem along the upper reaches of Cherry Creek has never been of great importance, probably because upper reaches of this stream are normally dry. Below the Denver Country Club, where ground water recharge and surface drains contribute significant flow to the stream, rats begin to appear. Illegal waste connections to the surface drains in this area are known to exist. Many rats have been observed by Project personnel near the confluence of Cherry Creek and the South Platte River on various occasions.

Future rat populations along the streams in the above areas will remain at or above their present levels as long as the present pollutional levels and harborage conditions exist. These rat populations can best be reduced through the elimination of the present sewage and industrial waste discharges to the streams and through the elimination of those conditions along the stream banks which provide good harborage for the rats.

(Figures 5, 6, 7, 8, 9 and 10 are as follows:)

Figure 5: South Platte River and Burlington Ditch Diversion at Denver-Adams County line. Notice well-cleared banks in Denver, but heavy brush and trash along the banks in Adams County providing good rat harborage.

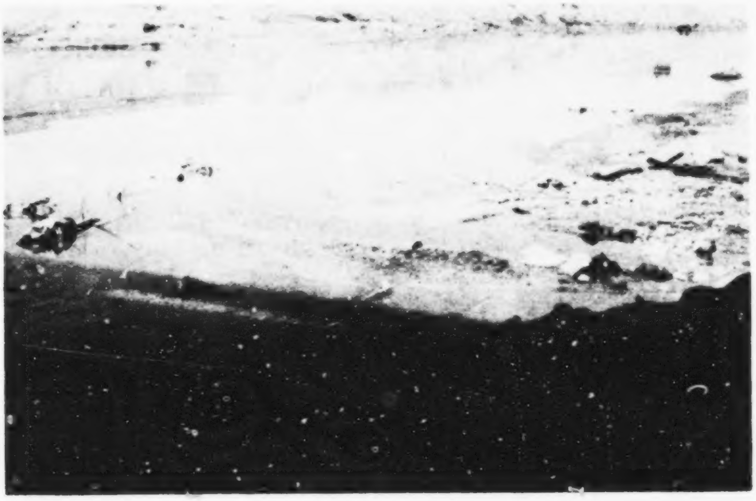


Figure 6: Delta of feed corn washed into the South Platte River by drain from Denver Union Stockyards. Just upstream (300 yards) from Denver Northside Sewage Treatment Plant.

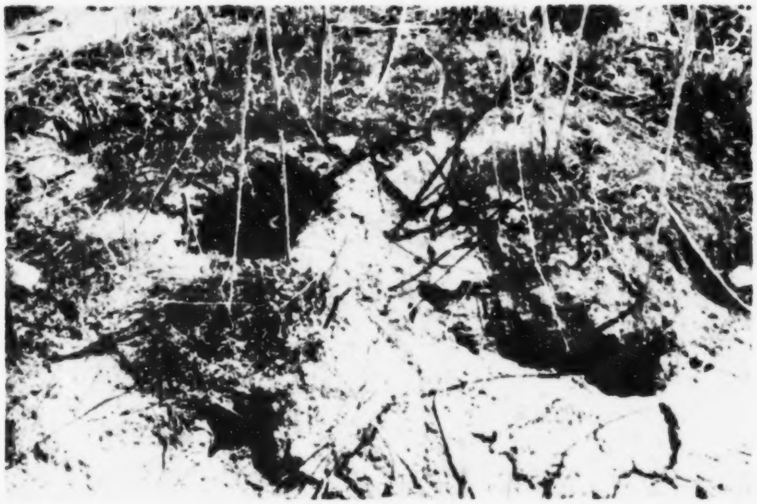


Figure 7: Rat burrows along east bank of South Platte River in vicinity of corn washings from Denver Union Stockyards.

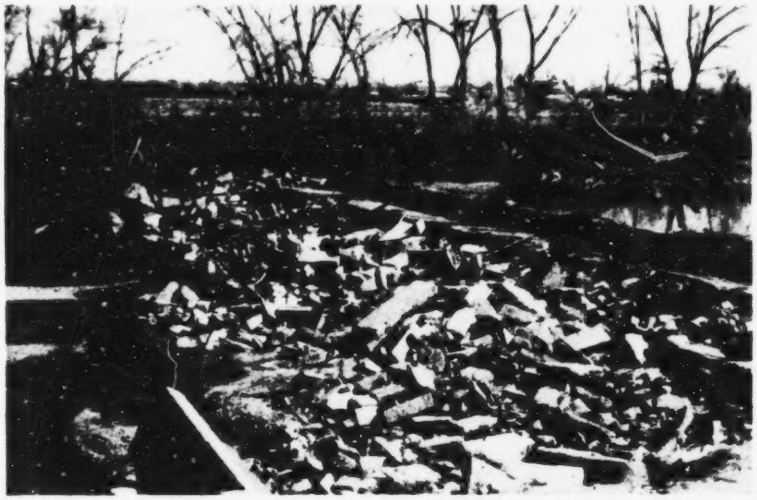


Figure 8: Excellent rat harborage in jumbled rock across South Platte River near York Street bridge in Adams County.

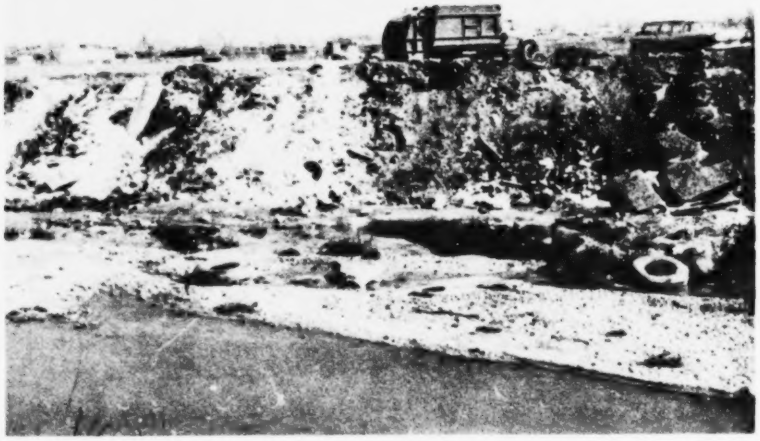


Figure 9: Denver City dump facing along Clear Creek just east of Federal Boulevard.

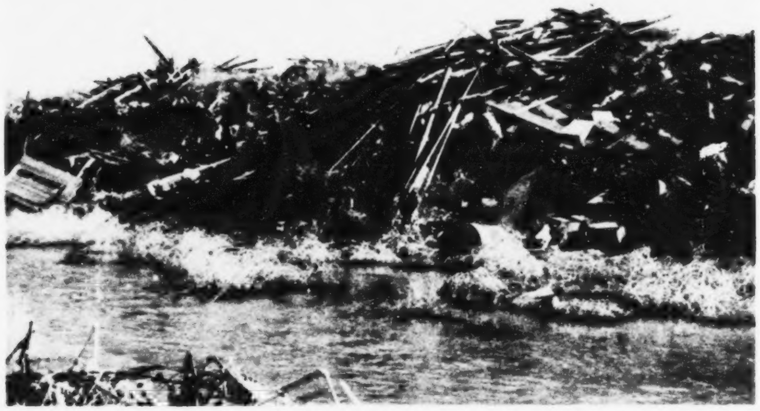


Figure 10: Dump along Sand Creek in back of Jorgensen hog farms just east of Dahlia Street. Excellent rat harborage.

M. A. Bauer

FIELD STUDIES: 1944-1962

The following reports taken from the files at CDC, Greeley, are presented here in summary form as a supplement to the foregoing presentation. While many of these reports have furnished the foundation for the previous discussions on rats and mosquitoes, not all of them have direct bearing on the situations of today. They do, however, provide insight into the history and nature of the vector problems within the South Platte River Basin.

"Report on the Fly and Rat Problem in North Denver and Adams County Areas during 1952" (8)

Recognizing that a serious fly problem existed in the northern Metropolitan Denver Area, several health agencies conducted a general survey to study the problem in 1952. Three hog farms and two fertilizer plants were checked periodically from May through September. These studies indicated the most serious problem was the breeding of flies in the paunch manure piles at the fertilizer plants, with the hog farms being of somewhat secondary importance. Little or no breeding took place in hog manures, but there was extensive breeding in the garbage being spread out to the hogs for feeding.

In conjunction with the above studies, an extensive rodent control study was also conducted through the summer of 1952. Observations were concentrated in the Washington Street-Platte River area and extending about one mile north beyond the Denver city limits into Adams County. General rat infestation was found throughout the area in association with feedlots, packinghouses, stockyards, dumps, fertilizer plants, manufacturing companies, retail outlets, truck farms, and others. It was also noted that the heaviest infestation was observed along the South Platte River and the Burlington Ditch. The report states that:

> "As would be expected, heavy infestation was observed along the Platte River and Burlington Ditch, where both waterways provide nesting sites and where gross pollution supplies the rat population with food needs. These watercourses are also used by the rats for paths of migration."

"A Reconnaissance of Domestic Rodent Control and Related Environmental Sanitation Problems at Sterling, Colorado" (9)

Domestic rodents had constituted a problem in and around the City of Sterling for a number of years and in 1959 the Northeast Colorado District Health Department requested assistance from the United States Public Health Service in evaluating the problem. An initial reconnaissance was made in June 1959 and a full review of the area was made in November 1959. Light infestation was generally found within the city, while medium to heavy infestation was found in the rural areas adjoining the city. The problems involved poor refuse storage and premise sanitation which provided both food supply and harborage for rats.

"A Preliminary Evaluation of the Fly and Mosquito Problems in the Brush-Fort Morgan Area of Colorado - June 27, 1957" (10)

On June 27, 1957, representatives of CDC, Greeley, and the Washington and Morgan County Health Departments made a spot survey of the fly and mosquito problem in the Brush-Fort Morgan areas. These two communities are located in the South Platte River Valley about sixty miles east of Greeley, Colorado. The fly problem was associated with poor sanitation practices. The most extensive breeding occurred at the various feedlots in accumulated manure. The sewage effluent from Brush collected in pools on a flat area adjacent to the South Platte River. Numerous rat-tailed maggots were observed in the effluent pools and the adult Syrphid flies were common. However, these flies appear to have little public health significance.

A spot survey was made of mosquito breeding habitats within the town of Brush, in the irrigated areas around Brush, at the Brush sewage outlet, and in the South Platte River bottom area near Fort Morgan and Brush. The primary location of mosquito breeding was observed to be the polluted seepage and flood water pools throughout the river bottom area. Mosquito larvae were collected from several locations, and were subsequently identified. Several species of Culex and Aedes mosquitoes were observed both in the larval and adult stages. The most prevalent mosquito was C. tarsalis, the primary vector of encephalitis in the Basin area. It was expected that heavy Culex breeding would be found in the pools of effluent below the Brush sewage outfall, but this was not the case, probably due to a recent "flushing" of the area by high water. The report states that:

> "The pools of effluent appeared to be ideal breeding sites for Culex pipiens and possibly

M. A. Bauer

"C. tarsalis where the contents were more dilute."

"Mosquito Survey - Longmont, Colorado, June 21, 1961" (11)

The significant waters included in this survey were the St. Vrain Creek, which flows just south of Longmont; Calkins Lake, which is to the east of Longmont; and several swampy areas to the south of the city lying just north of St. Vrain Creek and adjacent to the Burlington railroad tracks. While both Aedes and Culex mosquitoes were found, those of greatest significance were C. tarsalis, which is a vector of encephalitis. C. tarsalis was found to breed heavily in the Calkins Lake area, particularly along the fringe in pools somewhat isolated from the main lake by heavy vegetation. C. tarsalis was also found to breed in considerable numbers just north of St. Vrain Creek in the vicinity of the Longmont plant of the Great Western Sugar Company. The most significant breeding area of C. tarsalis was found just southeast of the city, well within the flight range of the mosquito. The waters in this area were contaminated by refuse disposal and had a strong odor of sewage.

M. A. Bauer

"Rodent Survey of Denver, Colorado, October-November, 1944" (12)

In 1944, infestation was found in all parts of Denver with the greatest density by far in the section along the South Platte River from West 46th Avenue to the Burlington Ditch. Several meat packing and feedlot operations which furnish a great deal of food for the rats are located in this area. Animal waste, blood and tissue were deposited in the river to become a floating menu for the rat population harbored along the banks in the shelter of the brush and riprap. The report states that:

> "The dumping of offal or putrescible wastes into the South Platte River is prohibited by city ordinance, yet enforcement of this law is lax or is not practiced. Edible matter floating down this river supports a considerable number of rats, and the proper treatment of this industrial waste is imperative."

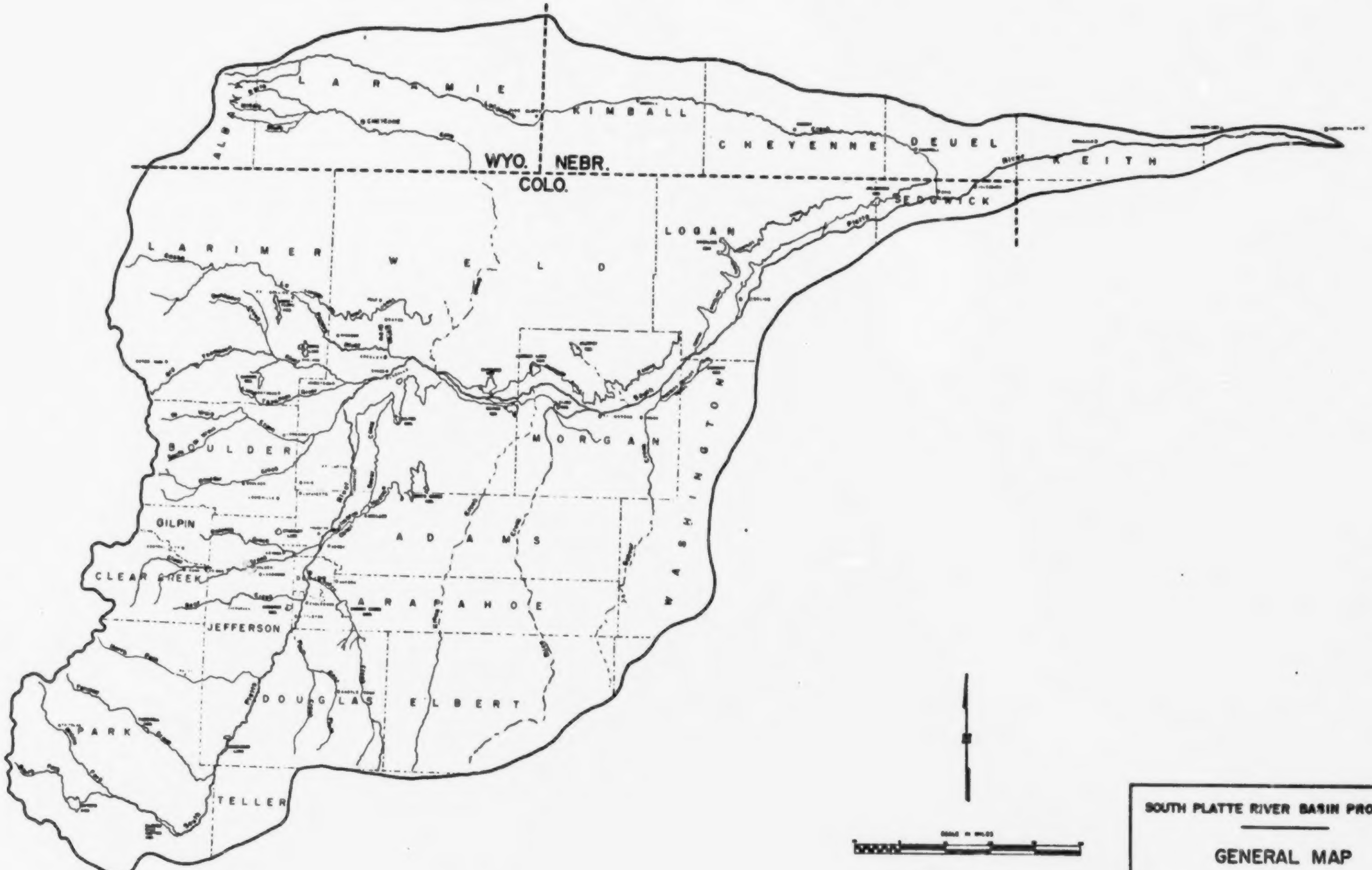
The report further states:

> "The conditions in the northern part of the city, along the South Platte, with its riprap banks and collections of rats in the packing house district, are most favorable to

"an extension of plague into the wholesale and other metropolitan areas if the disease appears on the north border of the city."

"Report of a Survey of Rodent Problems at Boulder and Longmont, Boulder County, Colorado, February 15, 1961" (13)

The rat problems in these cities arise largely from poor sanitation practices, particularly in the storage of refuse and garbage and the disposal of same. Further problems arise from poor practices in and around livestock feedlots, grain storage, and hog farms. Evidence of rats was observed along the stream which flows through the south part of the Boulder business district. Extensive harborage for rats was present in the form of weeds, tree roots, riprap and piles of lumber. A food supply in the form of improperly stored garbage was available along the banks.


WYO.
NEBR.
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ALBANY
LARAMIE
KIMBALL
CHEYENNE
DEUEL
KEITH
SEDGWICK
LOGAN
LARIMER
WELD
BOULDER
MORGAN
WASHINGTON
GILPIN
ADAMS
CLEAR CREEK
ARAPAHOE
JEFFERSON
DOUGLAS
ELBERT
PARK
TELLER
SCALE IN MILES

FEBRUARY 1964

SOUTH PLATTE RIVER BASIN PROJECT

GENERAL MAP

DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLO.

FIGURE 1

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M. A. Bauer

MUNICIPAL WASTE REPORT
METROPOLITAN DENVER AREA
SOUTH PLATTE RIVER BASIN

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Water Supply and Pollution Control
South Platte River Basin Project
Denver, Colorado

December 1965

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SOUTH PLATTE RIVER BASIN PROJECT

U. S. Public Health Service

Background and Objectives

On July 18, 1963, the Governor of Colorado requested the Secretary of Health, Education, and Welfare to assist the State in determining sources of pollution and quality of waters of the South Platte River Basin within the State of Colorado.

The First Session of the Conference in the Matter of Pollution of the South Platte River Basin was held in Denver, Colorado, on October 29, 1963, under the provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 466g). It was established at this conference that a study would be undertaken by facilities of the U. S. Public Health Service. Findings and recommendations from this study would lead to a program of pollution abatement to be developed jointly by the South Platte River Basin Project, Public Health Service, and the Colorado State Department of Public Health.

The long-range goals and objectives of the Project are as follows:

1. Determine the legitimate water uses and locate the sources of pollution having an adverse effect on those uses.
2. Through field investigations determine the physical, chemical, and biological responses of the river to pollution and evaluate the previously located sources of pollution with respect to the conditions in the river.
3. Compute the waste load reductions necessary to obtain desired water quality and recommend water quality control measures needed to effect the desired waste load reductions.

Organization

The South Platte River Basin Project consists of engineering and associated professional and clerical personnel. The Project headquarters offices are located in downtown Denver and the laboratory has been established at the Colorado State Department of Public Health, Denver, Colorado. The Project is administratively attached to the Water Supply and Pollution Control Program of the Public Health Service, U. S. Department of Health, Education, and Welfare, Region VIII, Denver, Colorado.

ACKNOWLEDGMENT

Throughout this study, effective coordination was maintained with interested Federal, State, county, municipal and district personnel. The Colorado State Department of Public Health has furnished the Project with past analyses of various treatment plant effluents. In addition, personnel of that agency provided valuable information concerning the design and operation of these plants. The Inter-County Regional Planning Commission was most helpful in providing information regarding the many sanitation districts. Without exception, the officials of the various municipalities and sanitation districts gave freely of their time and knowledge to assist in this study, by furnishing plant operating records, plant laboratory results, and system maps. Plant operators provided assistance in the collection of many samples for the study. The officials of Metropolitan Denver Sewage Disposal District No. 1 supplied extensive information concerning the new Metro facilities. The generous assistance given by the personnel of these agencies is gratefully acknowledged.

M. A. Bauer

SUMMARY

A study of municipal waste discharges in the Denver Metropolitan Area was undertaken by the Project during the period April 1, 1964 - December 31, 1964. Included in this study were 26 sewage treatment plants owned and operated by municipalities, sanitation districts, Federal and State agencies, or industries.

Interviews were held with plant officials in conjunction with a Project sampling program which included analysis of composite and grab samples. Additional operating data were furnished by plant operators and the Colorado State Department of Public Health.

Data for 23 plants were developed to reflect influent and effluent quality, and total loadings discharged to Basin streams. The remaining 3 plants were found to discharge no effluent to the South Platte River or its tributaries. Of the 26 plants, 22 receive essentially domestic waste and 4 receive both industrial waste and domestic waste.

Additional considerations of this investigation included an analysis of effects of the proposed Metropolitan Denver Sewage Disposal District No. 1 (MDSDD#1) treatment

facilities and the operation procedures practiced at the various municipal treatment plants in the Metropolitan Denver Area.

In close cooperation with the Colorado State Department of Public Health, a proposed pollution abatement schedule was developed which is based on current State Effluent Standards for waste discharges. Recommendations included in the abatement schedule require action to be completed before January 1, 1967, the estimated completion date for the new MDSDD#1 facilities.

CONCLUSIONS

1. The municipal waste facilities in the Metropolitan Denver Area at the present time are inadeuate. Eighteen of the 23 sewage treatment plants discharging to Basin streams in the study area do not conform to one or more of the State Standards for sewage effluent. Specifically, during the Project study, 18 plants did not conform to State Standards for coliform density, 15 plants did not conform to State Standards for Biochemical Oxygen Demand, and 9 plants did not conform to State Standards for suspended organic matter. These conditions can be attributed chiefly to insufficient plant capacity, lack of secondary treatment and poor operational procedures.

2. Significant progress in pollution abatement is now under way for 8 treatment plants affiliated with Metropolitan Denver Sewage Disposal District No. 1. The MDSDD#1 facilities, presently under construction, should provide a substantial reduction in pollutional loads to the Basin streams. The Adolph Coors Company, which operates treatment facilities in Golden, Colorado, is also engaged in a significant pollution abatement program. The construction of additional treatment units scheduled for the summer of 1966 will provide future capacity for this plant.

3. There are 4 entities which operate municipal treatment plants that have initiated corrective action to conform to State Standards for sewage effluent. All of these entities are either in the process of obtaining or have obtained feasibility reports relative to joining MDSDD#1.

4. Two communities operating municipal treatment plants that now conform to State Standards for sewage effluent with the exception of coliform density require engineering studies to improve plant operation or provide plant expansion in the near future.

5. Three plants which were found in violation of State Standards are not presently committed to a definite course of action.

6. The major portions of Basin streams in the Metropolitan Area are grossly polluted primarily as a result of excessive waste loads discharged from municipal treatment plants. Stream conditions in the lower portions of the study area at the time of the Project stream survey presented a picture of severe degradation.

7. Results of current Project programs relating to municipal water supply, farm irrigation, and pollution of ground water will be needed to determine the extent of damages to legitimate water use of Basin streams.

8. The Metropolitan planning concept, as embodied by the MDSDD#1, is a logical and economical solution to the problem of waste treatment in the Denver area.

9. On the basis of present Biochemical Oxygen Demand loads estimated by Project personnel, which are now in excess of projected loads derived by Denver Metro Engineers, it is likely that expansion of secondary treatment facilities at the MDSDD#1 plant will be necessary earlier than the anticipated date of 1980.

RECOMMENDATIONS

The following recommendations have been developed in close coordination with officials of the

Colorado State Department of Public Health. These officials are engaged in developing a program of corrective action with the communities involved.

1. The following plants do not provide adequate chlorination because of either lack of facilities or insufficient use of existing facilities. These entities should complete the necessary action to conform with State Effluent Standards for coliform density prior to January 1, 1967.

   - Thornton
   - North Washington
   - Baker
   - Westminster
   - Arvada
   - Clear Creek Valley
   - Wheatridge
   - Fruitdale
   - Northwest Lakewood
   - Denver Eastside
   - Aurora Westerly
   - South Lakewood
   - Englewood
   - Federal Correctional Institution
   - Evergren
   - Littleton
   - Adolph Coors Company
   - Buckley Air Station

2. Eight plants have joined the MDSDD#1, which will provide the means of correcting their present violation of State Standards with regard to BOD and with the exception of Fruitdale for organic suspended solids. Precautions must be taken to insure that whatever

wastes these plants do not convey to MDSDD#1, but continue to discharge to streams, are in compliance with State Standards. The eight plants are listed below:

North Washington
Baker
Westminster
Arvada
Wheatridge
Northwest Lakewood
Denver Eastside
Denver Northside

3. The four plants which have requested feasibility estimates relative to joining MDSDD#1 should complete such action as is necessary by January 1, 1967, to either gain membership in the MDSDD#1 or improve plant performance to insure conformance with State Standards for discharge of BOD, Organic Suspended Solids, Coliform, and Settleable Solids. These are:

Thornton
Fruitdale
Aurora (Westerly)
Clear Creek Valley

4. Three plants not presently engaged in a definite pollution abatement program should complete such action as is necessary by January 1, 1967, to insure conformance with State Standards for effluent discharges. These are:

South Lakewood
Federal Correctional Institution
Evergren

5. Engineering studies with regard to renovation and expansion of the Littleton Plant and with regard to operational procedures at the Englewood Plant should be completed by January 1, 1967.
6. Although the above recommendations are based on present State Standards for waste discharge, it should be understood that more stringent regulations may be necessary in some instances in order to insure minimum water quality in the receiving stream. These water quality objectives and requirements will be developed in the near future by the joint efforts of the South Platte River Basin Project and the Colorado State Department of Public Health in conjunction with a pollution abatement schedule for water quality control over the entire Basin.
7. An immediate study should be undertaken at the City of Westminster plant to provide interim measures designed to improve the operational procedures during the period of construction of MDSDD#1 plant. The facilities presently available at the Westminster plant appear capable of greater efficiencies in the reduction of BOD and total suspended solids.
8. As a general recommendation, all plants should conform

to the "Recommendations for Minimum Personnel, Laboratory Control, and Records for Municipal Waste Treatment Works," as adopted by the 1963 Conference of State Sanitary Engineers. To insure proper plant operation, the staff of the State Water Pollution Control Section should be increased to provide the necessary supervision and technical advice.

I. INTRODUCTION

This report presents the results of a field study of municipal wastes in the Metropolitan Denver Area during the period April 1, 1964, to December 31, 1964. The objectives of this investigation were to locate the sources of municipal waste discharges, to assess the present treatment facilities provided for those discharges, and in coordination.with the Colorado State Department of Public Health, to develop a pollution abatement schedule for such action as is indicated. The current State of Colorado laws governing the discharge of sewage effluents to State waters, upon which the pollution abatement schedule is based, are contained in Appendix A. A survey of municipal wastes in the remainder of the South Platte River Basin will be the subject of a subsequent report.

II. BACKGROUND AND DESCRIPTION

General Description of the Area

The City of Denver, capital of Colorado, is located in the north central portion of the State on the western edge of the Great Plains, approximately 50 miles east of the Continental Divide. The County of Denver has identical boundaries with the City, and both are considered as a single unit in a political as well as a geographical sense. In addition to Denver, the Metropolitan Area includes portions of Adams, Arapahoe, Boulder and Jefferson Counties. According to estimates obtained from the State Commerce and Development Division, the population in the City and County of Denver was 525,000 persons as of July 1, 1964, while the Metropolitan Area comprised about 1,000,000 persons. The Metropolitan Area includes about 700 square miles, which represents 6.7 percent of the area of the entire State. Within these confines about one-half of the total population of the State is located.

The South Platte River, which is 459 miles in length from its point of origin to the junction with the

North Platte River in Nebraska, flows diagonally from southwest to northeast through the Metropolitan Area. The river enters the Metropolitan Area south of Littleton at about river mile 325, and departs in Brighton in the vicinity of river mile 290 (1). The principal tributaries to the South Platte River in the Metropolitan Area are Bear Creek (river mile 320.9), Cherry Creek (river mile 312.), Sand Creek (river mile 306.8) and Clear Creek (river mile 305.5) (1). According to records maintained by the United States Geological Survey (USGS), the annual discharge from Bear Creek, Cherry Creek and Clear Creek is 24,470, 11,800, and 64,220 acre-feet respectively (2). Sand Creek contributes an annual flow of about 5,000 acre-feet, based on data from the State Engineer's office.

The valley-fill deposits of the South Platte River Valley in the Metropolitan Area consist chiefly of sand and gravel. Large amounts of ground-water are present at depths ranging from less than one foot to about 65 feet below the land surface. In this area, the base flow of the mainstem of the South Platte River is supplemented by large amounts of ground-water return flow. Conversely, certain tributaries, notably Sand Creek, contribute a portion of their flow to the shallow aquifer.

M. A. Bauer

Description and Location of Municipal Waste Treatment Facilities

There are about 100 separate entities directly involved in the collection and treatment of sewage in the Metropolitan Area. Treatment facilities are provided by 7 sanitary districts, 14 municipalities, and 5 institutions. The locations and types of treatment for these plants are indicated in Table I and Figure 1.

(Table I and Figure 1 are as follows:)

TABLE I

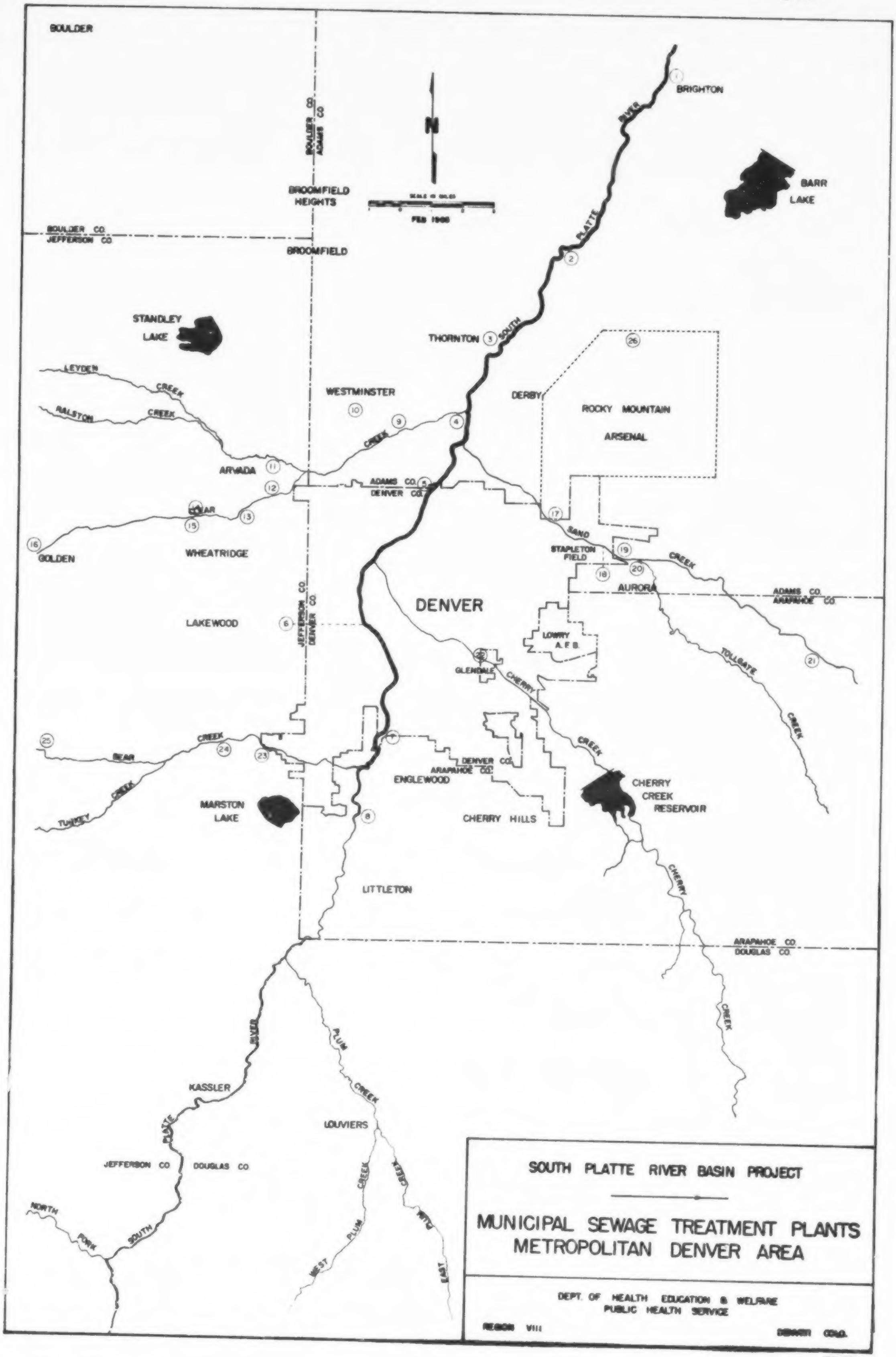
LOCATION OF MUNICIPAL SEWAGE TREATMENT PLANTS IN THE METROPOLITAN AREA

Map Ident. No.	Name of Facility	River Mileage	Type Treatment
1.	City of Brighton	289.5	Secondary
2.	S. Adams Water & San District	301.2	Secondary
3.	City of Thornton	303.5	Secondary
4.	N. Washington Water & San District	305.5	Secondary (c)
5.	Denver - Northside	308.8	Primary
6.	S. Lakewood San District	314.1/2.1 W	Secondary
7.	City of Englewood	319.7	Secondary
8.	City of Littleton	323.5	Secondary
9.	Baker Water & San District	305.5/3.0	Secondary
10.	City of Westminster	305.5/3.6/1.6	Primary
11.	City of Arvada	305.5/6.2/0.3	Secondary
12.	Clear Creek Valley San District	305.5/7.0	Secondary
13.	City of Wheatridge	305.5/7.5	Secondary
14.	Fruitdale San District	305.5/10.0	Primary
15.	N. W. Lakewood San District	305.5/10.2	Primary
16.	City of Golden	305.5/15.5	Secondary
17.	Denver - Eastside	306.8/4.7	Primary
18.	City of Aurora (Westerly)	306.8/5.5/1.1 S	Secondary
19.	City of Aurora (Sand Creek)	306.8/6.8	Secondary
20.	Fitzsimons Hospital	306.8/6.9/0.9	Secondary
21.	Buckley Air Station	306.8/11.9	Secondary
22.	City of Glendale	(a)	Secondary
23.	Colo. State Industrial School for Girls	(a)	Secondary
24.	Federal Correctional Institution	320.9/5.5	Secondary (c)
25.	City of Evergreen	320.9/19.3	Secondary (c)
26.	Rocky Mountain Arsenal	(b)	Secondary (c)

(a) Plant discharge to oxidation pond, no effluent.

(b) Discharges to First Creek, thence to Burlington Canal - Does not enter South Platte River.

(c) No secondary settling facilities available.


BOULDER
BOULDER CO.
ADAMS CO.
N
SCALE IN MILES
FEB 1960
BROOMFIELD HEIGHTS
BOULDER CO.
JEFFERSON CO.
BROOMFIELD
BRIGHTON
1
RIVER
BARR LAKE
PLATTE
2
SOUTH
THORNTON
3
STANDLEY LAKE
LEYDEN CREEK
RALSTON CREEK
WESTMINSTER
10
9
CREEK
4
DERBY
26
ROCKY MOUNTAIN ARSENAL
ARVADA
11
12
ADAMS CO.
DENVER CO.
5
17
CLEAR
15
13
14
16
GOLDEN
WHEATRIDGE
SAND
STAPLETON FIELD
18
19
20
CREEK
AURORA
ADAMS CO.
ARAPAHOE CO.
DENVER
JEFFERSON CO.
DENVER CO.
LAKEWOOD
6
LOWRY A.F.B.
22
GLENDALE
CHERRY
TOLLGATE
21
CREEK
25
CREEK
BEAR
24
23
7
DENVER CO.
ARAPAHOE CO.
ENGLEWOOD
CREEK
CHERRY CREEK RESERVOIR
TURKEY
CREEK
MARSTON LAKE
8
CHERRY HILLS
CHERRY
LITTLETON
ARAPAHOE CO.
DOUGLAS CO.
RIVER
PLUM
CREEK
KASSLER
LOUVIERS
PLATTE
JEFFERSON CO
DOUGLAS CO
CREEK
CREEK
NORTH
FORK
SOUTH
WEST
PLUM
EAST

SOUTH PLATTE RIVER BASIN PROJECT

MUNICIPAL SEWAGE TREATMENT PLANTS
METROPOLITAN DENVER AREA

DEPT. OF HEALTH EDUCATION & WELFARE
PUBLIC HEALTH SERVICE

REGION VIII

DENVER COLO.

FIGURE 1

The major treatment works is the Denver Northside plant, which has an average flow of about 70 million gallons per day (mgd) and serves an estimated 600,000 persons. The remaining 25 sewage treatment plants serve about 354,000 persons. On the basis of these data, municipal wastes for about 95 percent of the population of the Metropolitan Area receive treatment at those plants listed in Table I. The present overall reduction of 5-day 20°C Biochemical Oxygen Demand for these municipal treatment plants is about 50 percent. The wastes from the remaining 5 percent of the Metropolitan Area population, or 46,000 persons, are served by septic tanks or similar facilities.

Eighty-one percent of the treated wastes from the Denver Metropolitan Area are discharged to the South Platte River. As shown in Figure 1, there are 8 plants along the river which contribute an average discharge of 86.4 mgd. The 8 plants located along Clear Creek discharge 14.4 mgd. Sand Creek and Bear Creek receive wastes from 7 plants which discharge an average of 5.8 mgd. The 3 remaining facilities, largest of which serves 500 persons, do not discharge to Basin streams.

Metropolitan Denver Sewage Disposal District No. 1

In 1960, the Colorado State Legislature passed an act permitting formation of a Metropolitan Disposal District in any metropolitan area in Colorado. This legislation was sponsored by the Joint Sanitation Commission, composed of a number of interested districts and municipalities within the Metropolitan Area, and the Inter-County Regional Planning Commission. As a result of this action, the Metropolitan Denver Sewage Disposal District #1 (MDSDD#1) was formed, and provisions were made for an engineering study. The firms of Phillips-Carter-Osborne, Inc., Ken R. White, Inc., and Henningson, Durham, and Richardson, Inc., were retained as consultants under the name of Denver Metro Engineers. The engineers provided the pre-design report in 1961 which proposed the construction of a new metropolitan sewage treatment plant and revisions to the existing Denver Northside Plant (3). Essentially the new plant would provide primary and activated sludge treatment with sludge drying and/or incineration. The present Denver Northside facility would be used for primary treatment only, and its effluent delivered to the proposed MDSDD#1 Metro plant for secondary treatment. All sewage received by the MDSDD#1 plant from areas not served by the Denver Northside plant, would receive both primary and secondary treatment.

M. A. Bauer

In addition to the treatment works, a system of interceptors was proposed which would convey the sewage to the plants. Primarily these collection facilities included interceptors to be constructed along portions of Bear Creek, Sand Creek, the South Platte River and Clear Creek. The location of the Metropolitan Denver treatment plants affiliated with MDSDD#1, interceptors, and area served are shown in Figure 2.

(Figure 2 is as follows:)

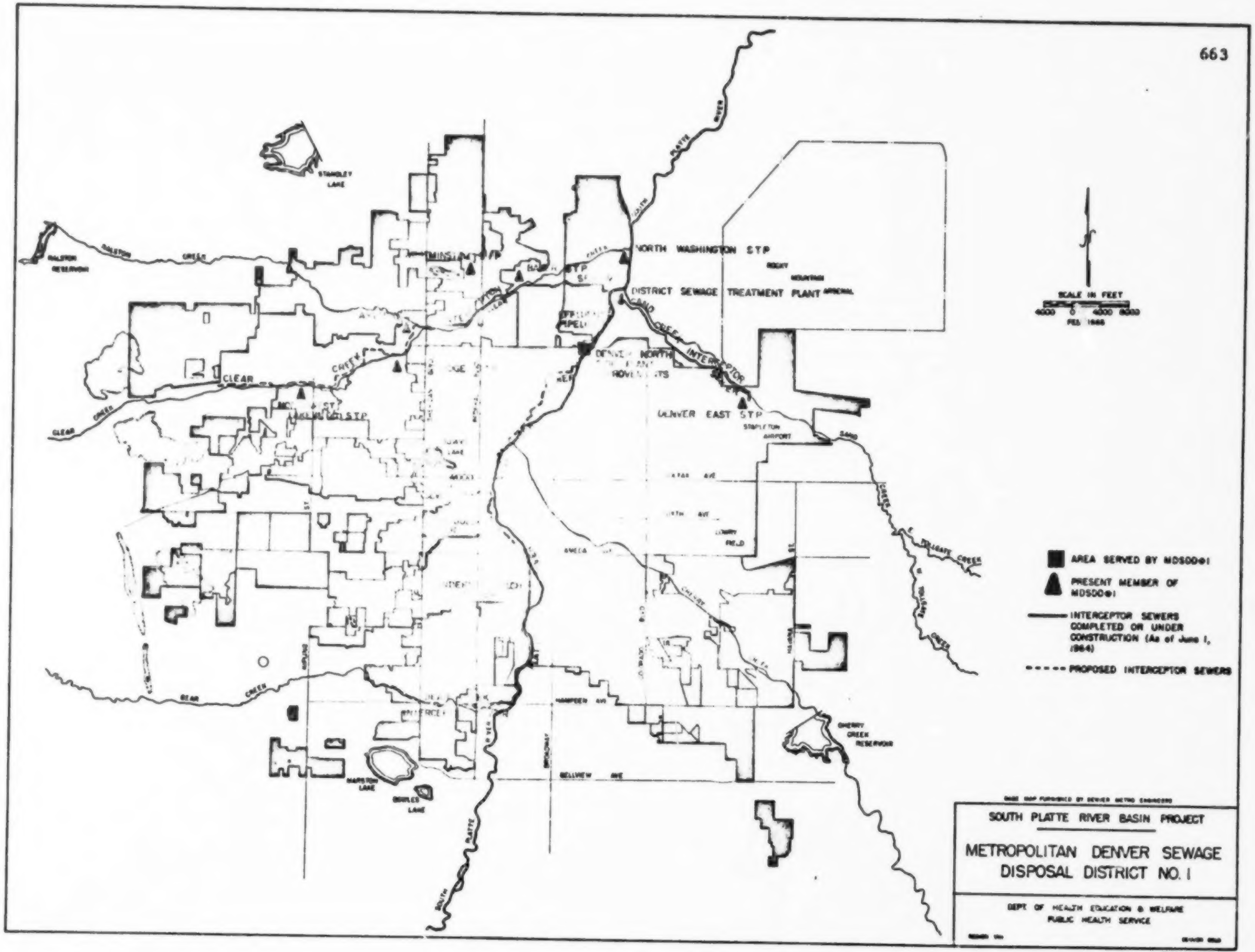

STANDLEY LAKE
RALSTON RESERVOIR
RALSTON CREEK
CLEAR CREEK
NORTH WASHINGTON STP
ROCKY MOUNTAIN ARSENAL
DISTRICT SEWAGE TREATMENT PLANT
SAND CREEK INTERCEPTOR SEWER
DENVER NORTH
DENVER EAST STP
STAPLETON AIRPORT
SOUTH PLATTE RIVER
COLFAX AVE
LOWRY FIELD
CHERRY CREEK
CHERRY CREEK RESERVOIR
E. TOLLGATE CREEK
W. TOLLGATE CREEK
SAND CREEK
BEAR CREEK
HAMPDEN AVE
BELLVIEW AVE
BROADWAY
MARSTON LAKE
BOWLES LAKE
SCALE IN FEET
4000 0 4000 8000
FEB 1966
■ AREA SERVED BY MDSDD#1
▲ PRESENT MEMBER OF MDSDD#1
INTERCEPTOR SEWERS COMPLETED OR UNDER CONSTRUCTION (As of June 1, 1964)
PROPOSED INTERCEPTOR SEWERS
SOUTH PLATTE RIVER BASIN PROJECT
METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1
DEPT OF HEALTH EDUCATION & WELFARE
PUBLIC HEALTH SERVICE

FIGURE 2

The pre-design report was accepted and authorization given to prepare final plans. In 1963, the final plans for the first phase of interceptor construction were approved by the Colorado State Department of Public Health (CSDPH), and a contract was awarded. In 1964, the final plans for the MDSDD#1 plant and revisions for the Denver Northside plant were also approved and contracts awarded. Construction of these projects is currently under way and completion of all work is contemplated prior to January 1967.

The MDSDD#1 sewage treatment plant will have an initial capacity of 27 mgd for primary treatment facilities, and 117 mgd for secondary treatment facilities. The revised Denver Northside plant will provide a capacity for primary treatment of 97 mgd with BOD reduction of 35 percent. The initial design for both plants combined will provide treatment for 262,000 pounds of BOD daily, with an average removal of 90-95 percent (3).

A total of 46 municipalities and sanitary districts will be served by the MDSDD#1 facilities. Among these agencies there are presently 8 sewage treatment plants in operation, including both Denver plants. Four of these plants now provide primary treatment only. The Denver East Side primary plant will be abandoned and the raw wastes conveyed to the MDSDD#1 facility. The Denver Northside plant will operate in conjunction with the MDSDD#1 facilities. The Northwest Lakewood and Westminster plants may continue operating, but all effluent will be diverted to MDSDD#1 for further treatment. The remaining 4 plants, all of which provide secondary treatment, will have an option of either discharging all wastes, raw or partially treated, into an interceptor, or discharging a portion of effluent to the stream in conformity with State effluent standards and the remainder to the interceptor. It is likely that these treatment plants, with the exception of the Denver facilities, will ultimately be abandoned and all raw wastes conveyed to MDSDD#1. It should be noted that under the agreement between the MDSDD#1 and the member districts and municipalities, no plant can enlarge its present facilities without permission from the Metro District. Based upon the population presently served by agencies committed to membership in MDSDD#1, it is estimated that approximately 75 percent of all persons living within the Metropolitan Area will be served by the MDSDD#1.

Present State Laws Governing Waste Discharge

The Colorado General Assembly has enacted legislation contained in Chapter 66 of the Colorado Revised Statutes concerning the power of the State Department of Public Health to establish the quality of the effluent of sewerage systems and trade wastes that are discharged. This authority has been promulgated in the form of regulations. In addition, the statutes prescribe permissible effluent from domestic sewage systems in terms of specific standards. In essence, these laws provide that the effluent of domestic sewerage systems shall not contain settleable and suspended organic matter exceeding 0.5 ml/l and 75 mg/l, respectively, shall not exceed 1,000 coliform organisms per milliliter when at least 4 samples are collected on 4 consecutive days, and shall not contain dissolved or suspended matter exceeding 50 mg/l in terms of a five-day 20-degree Centigrade Biochemical Oxygen Demand. If the effluent of a sewerage system is discharged into a watercourse used downstream as a surface source of public domestic water supply, the regulations of the Colorado State Department of Public Health state that the dissolved or suspended matter shall not exceed 30 mg/l in terms of five-day, 20-degree Centigrade BOD.

That portion of current statutes which pertains to the effluent from sewerage systems is outlined in Appendix A of this report.

III. CONDUCT OF THE SURVEY

Interview and Plant Visits

Project personnel visited each of the sewage treatment plants operating in the Metropolitan Denver Area. Interviews were held with institution, municipal and sanitation district officials, including managers, superintendents and operators. The types and condition of treatment units were examined and evaluated at each plant. A check of operating methods and records was made in order to determine variations and amounts of flow, as well as strength of influent and effluent sewage. Together with plant officials, estimates were made concerning the number of persons served by each treatment works. Wherever possible, an estimate of the amount of industrial waste flow to the treatment plant was determined. Such information included the name, type and location of the industry involved. Particular attention was paid to treatment facilities that appeared obsolete and poorly maintained or operated. Additional factors investigated included provision for bypass of sewage, the laboratory procedures followed, and the general degree of competence and training possessed by the plant operators.

Individual sewage treatment plant reports for each of the facilities in the Metropolitan Denver Area are contained in Appendix B, which is published under separate cover.

Procedures

A total of 21 plants was chosen for a waste sampling program which was carried out over a period of nine months, from April through December 1964. Selection of these plants was based primarily on the lack of sufficient or conclusive performance data. Each plant was sampled for a period of two to five days.

Composite samples of the influent and effluent were collected hourly from 8:00 a.m. to 3:00 p.m. each day by the plant operators, and were composited on the basis of flow at the time of collection. In addition, grab samples were collected by Project personnel at various times each day of the sampling period. All samples were analyzed at the Project Laboratory in accordance with "Standard Methods for the Examination of Water and Wastewater" (5). Composite samples were examined for biochemical oxygen demand, total suspended solids, volatile suspended solids, and settleable solids. Grab samples were analyzed for total and fecal coliform, and chlorine residual where applicable. Tabulation of all sampling results is included with the individual plant reports contained in Appendix B.

IV. MUNICIPAL WASTE DISCHARGE

General

The discharges from sewage treatment plants vary in terms of the types of waste received and the degree of treatment provided. Several plants, including Denver Northside, Golden North Washington, and Clear Creek Valley, receive significant amounts of industrial waste in addition to domestic sewage. Waste loads to the South Platte River and its tributaries from municipal plant effluents have been summarized on the basis of pounds of BOD, pounds of suspended solids and numbers of coliforms discharged daily to the mainstem and the affected tributaries. The latter include Bear Creek, Sand Creek, and Clear Creek.

Of the 23 sewage treatment plants currently operating in the Metropolitan Denver Area and discharging to Basin streams, Project waste-sampling activities were conducted at 21 plants to obtain more accurate estimates of pollutional loading to the streams. Sufficient data were available to provide satisfactory estimates for the remaining two plants. In Table II bacteriological loading from 23 plants which discharge to Basin streams is summarized.

Domestic Loading

Twenty-two sewage treatment plants in the Denver Metro area receive essentially domestic wastes. In Tables III and IV estimated daily biochemical oxygen demand and total suspended solids loadings to the streams are shown for 19 of these plants.

(Tables II, III and IV are as follows:)

TABLE II

MUNICIPAL SEWAGE TREATMENT PLANTS EFFLUENT BACTERIOLOGICAL LOADING

Map Ident. No.	Name of Plant	Median Total Coliform MPN/100 ml	Median Fecal Coliform MPN/100 ml
1.	City of Brighton	520	48
2.	S. Adams Water & San. District	5,200	1,600
3.	City of Thornton	36,000,000	7,500,000
4.	N. Washington Water & San. District	45,000,000	12,000,000
5.	Denver - Northside	30,000	19,000
6.	S. Lakewood San. District	160,000 (a)	---
7.	City of Englewood	3,700,000 (a)	---
8.	City of Littleton	5,400,000 (a)	---
9.	Baker Water & San. District	9,700,000	5,100,000
10.	City of Westminster	37,000,000	13,000,000
11.	City of Arvada	7,600,000	1,500,000
12.	Clear Creek Valley San. District	8,300,000	3,100,000
13.	City of Wheatridge	1,700,000 (a)	---
14.	Fruitdale San. District	59,000,000 (a)	---
15.	N. W. Lakewood San. District	6,600,000	4,700,000
16.	City of Golden	790,000 (a)	---
17.	Denver - Eastside	140,000	67,000
18.	City of Aurora (Westerly)	4,200,000	1,200,000
19.	City of Aurora (Sand Creek)	18	42
20.	Fitzsimons Hospital	20,000	5,600
21.	Buckley Air Station	79,000	36,000
24.	Federal Correctional Institution	2,600,000 (a)	---
25.	City of Evergreen	3,300,000	460,000

(a) Data furnished by Colorado State Department of Public Health.

TABLE III

MUNICIPAL SEWAGE TREATMENT PLANTS
(Predominantly Domestic Loading)

Map Ident. No.	Name of Plant	Pop. Served	FLOW Total 24 hrs.	 Gal/cap /day	 Total 8 hrs	 Ratio 8 hrs/24hr	INFLUENT BOD 8-hr Samp Period	 8-hr Samp Period	 8-hr Samp Period	 24 hrs. Est.	 24 hrs. Est.	EFFLUENT BOD 8-hr Samp Period	 Effi- ciency	 24 hrs Est.	 P. E. Est.
			(M.G.)	(Gal)	(M.G.)	(%)	(mg/1)	(lbs)	(lbs/cap)	(lbs)	(lbs/cap)	(mg/1)	(%)	(lbs)	
1	Brighton	7,500	0.65	87	0.237	36.5	220	435	0.058	880	0.117	12	95	45	280
2	S. Adams	16,000	1.5	94	0.564	37.6	300	1,410	0.088	2,855	0.178	26	91	255	1,600
3	Thornton	35,000	2.6	74	1.024	39.4	365	3,115	0.089	6,310	0.180	205	44	3,535	22,000
7	Englewood	55,200	4.5	82	1.66	36.8	240	3,325	0.060	6,735	0.122	48	80	1,350	8,440
8	Littleton	23,000	2.6	113	1.00	38.5	235	1,960	0.085	3,970	0.172	43	82	715	4,470
9	Baker	17,500	1.5	86	0.645	43.0	265	1,425	0.081	2,885	0.164	150(b)	43(b)	1,645	10,300
10	Westminster	17,500	1.3	74	0.536	41.2	345	1,540	0.088	3,120	0.178	335	3	3,025	18,900
11	Arvada	36,000	3.5	97	1.34	38.3	280	3,130	0.086	6,340	0.176	210(b)	25(b)	4,755	29,700
13	Wheatridge	20,500	1.8	88	0.745	41.4	355	2,205	0.107	4,465	0.217	95	73	1,210	7,560
14	Fruitdale	1,600	0.20	125	0.074	37.7	175	108	0.098	320	0.200	110	37	200	1,250
15	N.W.Lakewood	21,000	1.9	90	0.766	40.3	265	1,695	0.080	3,430	0.163	215	19	2,780	17,400
17	Denver (East)	18,000	1.4	78	0.594	42.4	340	1,685	0.093	3,410	0.189	205	40	2,050	12,800
18	Aurora (West.)	55,000	3.1	56	1.28	41.3	315	3,365	0.061	6,815	0.123	64	80	1,365	8,530
19	Aurora (Sand)	9,000	0.66	73	0.290	44.0	255	615	0.068	1,245	0.138	20	92	100	625
20	Fitzsimons	2,900	0.47	160	0.201	42.7	300	505	0.174	800	0.275	27	91	70	440
21	Buckley	400	0.05	125	0.020	39.5	135	25	0.062	50	0.125	23	83	9	55
6	So. Lakewood	6,500	0.55	85	0.200	36.2	270	450	0.069	910	0.140	52	81	175	1,100
24	F.C.I.	425	0.060	140	0.023	39.4	570	110	0.258	165	0.388	165	71	50	315
25	Evergreen	700	0.065	93	0.026	39.4	260	55	0.078	110	0.157	80	69	35	220
		343,725	29.205	85(a)	11.526	39.4(a)	283(a)	27,208	0.079(a)	54,815	0.160(a)	120(a)	57.5(a)	23,369	146,000

(a) Weighted Average.

(b) Including effects of sewage bypassed directly to Clear Creek.

NOTE: All BOD values based on 5-day 20° C Analysis.

TABLE IV
TOTAL SUSPENDED SOLIDS FOR MUNICIPAL SEWAGE TREATMENT PLANTS
(Predominantly Domestic Loading)

Map Identification No.	Name of Plant	Pop. Served	FLOW				INFLUENT TOTAL SUSPENDED SOLIDS					EFFLUENT TOTAL SUSPENDED SOLIDS		
			Total 24 hrs. (M.G.)	Gal/cap /day (Gal)	Total 8 hrs (M.G.)	Ratio 8 hrs/24 hr (%)	8-hr Samp. Period (mg/l)	8-hr Samp. Period (lbs)	8-hr Samp. Period (lbs/cap)	24 hrs. Est. (lbs)	24 hrs. Est. (lbs/cap)	8-hr Samp. Period (mg/l)	Effi-ciency (%)	24 hrs. Est. (lbs)
1	Brighton	7,500	0.65	87	0.237	36.5	209	413	0.055	1020	0.136	34	83.7	170
2	S. Adams	16,000	1.5	94	0.564	37.6	329	1545	0.097	3810	0.238	55	83.3	640
3	Thornton	35,000	2.6	74	1.024	39.4	554	4730	0.135	11650	0.300	212	61.7	4460
7	Englewood	55,200	4.5	82	1.66	36.8	241	3330	0.061	8210	0.150	43	82.2	1460
8	Littleton	23,000	2.6	113	1.00	38.5	197	1640	0.071	4040	0.175	38	80.7	780
9	Baker	17,500	1.5	86	0.645	43.0	251	1350	0.077	3330	0.190	105(b)	58.2(b)	1390
10	Westminster	17,500	1.3	74	0.536	41.2	289	1290	0.074	3180	0.182	196	32.2	2160
11	Arvada	36,000	3.5	97	1.34	38.3	275	3065	0.086	7580	0.210	209(b)	24.0(b)	5760
13	Wheatridge	20,500	1.8	88	0.745	41.4	288	1790	0.087	4420	0.215	64	77.8	980
14	Fruitdale	1,600	0.20	125	0.074	37.7	125	77	0.048	190	0.119	75	40.0	110
15	N. W. Lakewood	21,000	1.9	90	0.766	40.3	360	2325	0.111	5750	0.274	126	65.0	2010
17	Denver (East)	18,000	1.4	78	0.594	42.4	330	1630	0.091	4020	0.223	85	74.2	1040
18	Aurora (West.)	55,000	3.1	56	1.28	41.3	270	2880	0.052	7110	0.131	77	71.5	2030
19	Aurora (Sand)	9,000	0.66	73	0.290	44.0	248	600	0.067	1480	0.165	42	83.1	250
20	Fitzsimons	2,900	0.47	160	0.201	42.7	270	452	0.156	1115	0.384	36	86.7	150
21	Buckley	400	0.05	125	0.020	39.5	194	32	0.081	79	0.197	40	79.4	20
6	So. Lakewood	6,500	0.55	85	0.200	36.2	243	405	0.062	1000	0.154	76	68.7	310
24	F.C.I.	425	0.060	140	0.023	39.4	281	54	0.127	133	0.314	80	71.5	40
25	Evergreen	700	0.065	93	0.026	39.4	404	88	0.125	217	0.310	86	78.7	50
		343,725	29.205	85(a)	11.526	39.4(a)	282(a)	27696	0.081(a)	68334	0.200(a)	88(a)	65.2(a)	23810

(a) Weighted Average.

(b) Including effects of sewage bypassed directly to Clear Creek

The remaining three plants do not discharge to Basin streams. BOD data indicated an average of 0.079 pounds per capita for these plants during the eight-hour daytime period. For the 24-hour period, a figure of 0.160 pounds of BOD/cap. was assumed as a reasonable value for plants in the Metro Denver Area. An earlier study conducted by the Denver Metro Engineers for six plants included in Table II derived an average value of 0.159 pounds of BOD/cap/day (6). The ratio between the per capita loading values of 0.079 pounds and 0.160 pounds indicates that about 50 percent of the daily BOD load is received during the 8-hour daytime period.

A similar evaluation in the case of TSS indicated a value of 0.081 pounds/cap-8-hour sampling period for these plants. In the 24-hour period, a figure of 0.20 pounds of TSS per capita was assumed as a reasonable value. The ratio between these per capita loadings indicates that about 40 percent of the daily TSS load is received during the 8-hour daytime period.

The percentages of 50 and 40 were applied to the 8-hour loads computed for BOD and TSS respectively and estimates were obtained for loading to each plant for the 24-hour period. Plant efficiencies in BOD and TSS removal were obtained from average influent and effluent values for these characteristics during the sampling period. These values were applied to the 24-hour loading for these plants and an estimate of pounds of BOD and TSS discharged to the stream was made.

The treatment plants with essentially domestic loading are summarized below.

City of Brighton STP

This low-rate trickling filter plant, which serves 7,500 persons, provides an efficiency of 95 percent for BOD removal, and 84 percent for suspended solids removal according to Project sampling data. The present flow of 0.65 mgd is well below the plant design capacity. Adequate and well operated chlorination facilities are present at this plant. Daily loading to the South Platte River is estimated at 45 pounds of BOD and 170 pounds of suspended solids. Effluent coliform densities averaged 520 MPN per 100 ml for total coliform, and 48 MPN per 100 ml for fecal coliform.

South Adams Water and Sanitation District STP

The South Adams plant, which employs a high-rate trickling filter, operates with efficiencies of 91 percent removal for BOD and 83 percent removal for suspended solids according to Project sampling data. This serves about 16,000 persons, and receives average flows of 1.5 mgd, which are well under the present design capacity. Chlorination facilities and operation are considered adequate. Daily loading to the South Platte River is estimated to be 255 pounds of BOD and 640 pounds of suspended solids. Average effluent coliform values were found to be 520 MPN per 100 ml for total coliform, and 160 MPN per 100 ml for fecal coliform.

City of Thornton STP

The population served by this facility is 35,000 and daily waste flows were found to be 2.6 M.G. The plant, which uses a high-rate trickling filter, is designed for 1.9 mgd. According to Project sampling data, the plant efficiency in terms of BOD removal was only 44 percent, with 3,535 pounds discharged daily, while 4,460 pounds of suspended solids were discharged each day, indicating a plant efficiency of 62 percent. Both BOD and suspended solids values in the plant effluent were consistently above State Standards. In addition, the lack of adequate chlorination facilities was reflected in the effluent coliform densities, which averaged 36,000,000 MPN per 100 ml for total coliform, and 7,500,000 MPN per 100 ml for fecal coliform.

City of Englewood STP

This municipality operates two plants, both using the high-rate trickling filter process. These plants, which are designed for a combined capacity of 8 MGD, utilize a single outfall to discharge effluent to the South Platte River. The average daily flow received at these plants amounts to 4.5 mgd, and an estimated 55,000 persons are served. Project sampling data indicated plant efficiencies of 80 and 82 percent for BOD and suspended solids removal, respectively. Daily loading to the river was estimated at 1,350 pounds of BOD and 1,460 pounds of suspended solids.

City of Littleton STP

This plant serves about 23,000 persons, and has an average daily flow of 2.6 mgd. The design capacity of this trickling filter operation is rated at 2.8 mgd. There are no chlorination facilities and the coliform densities are considerably greater than State Standards. Project sampling data indicated plant efficiencies of 82 percent for BOD removal, and 81 percent for suspended solids removal. Daily loading to the river was estimated at 715 pounds of BOD, and 780 pounds of suspended solids. A comparison of present average daily flow and rated capacity indicates that planning for expansion of plant facilities should be initiated immediately.

Baker Water and Sanitation District STP

The District plant, which employs the high-rate trickling filter process, serves about 17,500 persons and has an average daily flow of 1.5 mgd. This facility is rated at a capacity of 1 mgd, and plant effluent values are consistently greater than State Standards. In addition, a portion of raw sewage is bypassed during periods of peak flow. There are no chlorination facilities provided for this plant. Project sampling data indicated plant efficiencies, including that portion which was bypassed, were 43 percent for BOD removal and 58 percent for suspended solids removal. Daily loading to Clear Creek was estimated to be 1,645 pounds of BOD, and 1,390 pounds of suspended solids.

City of Westminster STP

This plant only provides primary treatment, since the trickling fitler units are presently being bypassed. The average daily flow, on the basis of 17,500 persons served, is estimated at 1.3 mgd. The rated plant capacity is also 1.3 mgd. Although chlorination facilities are provided at this facility, they were not in use. Project sampling data indicated daily loading to Clear Creek of 3,025 pounds of BOD and 2,160 pounds of suspended solids. Plant efficiencies showed virtually no BOD removal, and 32 percent removal of suspended solids. It appears that, although the plant is affiliated with MDSDD#1 for future disposal of sewage, an immediate effort to improve plant efficiency should be made.

City of Arvada STP

This sewage treatment plant serves about 36,000 persons and is greatly overloaded. The average daily flow of 3.5 mgd is well in excess of the rated plant capacity of 0.75 mgd. Consequently, about 2.4 mgd of raw sewage is bypassed to Clear Creek without treatment. No chlorination facilities are provided at this plant. Project sampling data indicated plant efficiencies, including the effects of that portion which is bypassed, were 25 percent for BOD removal, and 24 percent for suspended solids removal. Total daily loading was estimated at 4,755 pounds of BOD and 5,760 pounds of suspended solids.

Wheatridge Sanitation District STP

This plant employs the standards trickling filter process and serves 20,500 persons. It receives a flow of 1.8 mgd which equals the plant design capacity. According to Project sampling data, the plant achieves 73 percent BOD removal, discharging 1,200 pounds to Clear Creek daily; 980 pounds of suspended solids are also discharged daily, from a total of 4,420 pounds received, resulting in 78 percent removal. Chlorination facilities are provided at this plant.

Fruitdale Sanitation District STP

The District operates a primary plant serving about 1,600 persons. Although the facilities are adequate as far as capacity is concerned, the lack of sufficient means of treatment results in violation of State Standards.

Project sampling data indicated plant efficiencies of 37 percent for BOD removal and 40 percent for suspended solids removal. Daily loading to Clear Creek was estimated at 200 pounds of BOD and 110 pounds of suspended solids. No chlorination facilities are provided at this plant.

Northwest Lakewood Sanitation District STP

This plant, which serves 21,000 persons, provides primary treatment and receives flows equal to its design capacity of 1.9 mgd. No chlorination facilities are present. Project sampling data showed plant efficiencies of 19 percent for removal of BOD and 65 percent for removal of suspended solids. It was estimated that Clear Creek receives daily loads of 2,780 pounds of BOD and 2,000 pounds of suspended solids. Bacteriological loading averaged 6,600,000 MPN per 100 ml of total coliform, and 4,700,000 MPN per 100 ml of fecal coliform.

City and County of Denver Eastside STP

This plant is the smallest of two facilities operated by Denver. It serves 18,000 persons and has an average flow of .4 mgd. The plant operates primary facilities including chlorination equipment. Project sampling data indicated the plant effluent in excess of State Standards. Plant efficiency for BOD reduction was 40 percent, and 74 percent for suspended solids reduction. Daily loading to Sand Creek was estimated at 2,050 pounds of BOD and 1,040 pounds of solids. Poor chlorination practices resulted in bacteriological loading of 140,000 MPN per 100 ml for total coliform, and 67,000 MPN per 100 ml for fecal coliform.

City of Aurora - Westerly Creek STP

This trickling filter plant is the largest of two facilities operated by Aurora. The plant design capacity of 2.5 mgd has been exceeded, as the 55,000 persons served contribute over 3 mgd average flow. Consequently, the effluent to Sand Creek is in violation of State Standards. Plant efficiencies were 80 percent reduction for BOD, and 72 percent reduction for suspended solids. Project sampling data indicated an estimated 1,350 pounds of BOD, and 2,030 pounds of suspended solids were discharged daily into the stream. Bacteriological loading averaged 4,200,000 MPN per 100 ml for total coliform, and 1,200,000 MPN per 100 ml for fecal coliform, indicating unsatisfactory operation of existing chlorination facilities.

City of Aurora - Sand Creek STP

This extended aeration type plant is the smaller of two facilities operated by Aurora. About 9,000 persons are served, and contribute an average flow of 0.7 mgd. This plant has a rated capacity for 1.0 mgd. In addition, the plant is well operated and is in conformance with State Standards. Project sampling data indicated daily loading to Sand Creek was 100 pounds of BOD, resulting in a plant efficiency of 92 percent, and 250 pounds of suspended solids, providing a plant efficiency of 83 percent. Bacteriological loading to the streams averaged 180 MPN per 100 ml for total coliform, and 4.2 MPN per 100 ml for fecal coliform, indicating satisfactory chlorination operation.

Fitzsimons Army Hospital STP

This high-rate trickling filter plant is operated by the Department of the Army and, following chlorination and detention in a polishing pond, the effluent is discharged to Sand Creek. The plant is well operated and is in conformity with State Standards. Based on plant operating records for the past two years, the efficiency of BOD reduction averaged 91 percent, while the efficiency of suspended solids removal averaged 87 percent. Daily loading to Sand Creek was estimated at 70 pounds of BOD and 20 pounds of suspended solids. Project sampling data indicated bacteriological loading averaged 20,000 MPN per 100 ml for total coliform and 5,600 MPN per 100 ml for fecal coliform.

Buckley Air Station STP

This trickling filter plant was designed to handle a capacity of 1.5 mgd during World War II; however, a substantial reduction of base personnel has resulted in a present average flow of 0.05 mgd. Project sampling data indicate plant efficiencies of 83 percent for BOD removal, and 79 percent for suspended solids reduction. Daily loading to Tollgate Creek averages 9 pounds of BOD and 20 pounds of suspended solids. No chlorination facilities are provided at this plant.

South Lakewood Sanitation District STP

The District operates an extended aeration plant which receives 0.6 mgd of sewage, which is the plant's capacity, from about 6,500 persons. Project sampling data indicated plant efficiencies of 81 percent for BOD removal, and 69 percent for suspended solids removal. Daily loading to the South Platte River was estimated to be 175 pounds of BOD and 310 pounds of suspended solids. This plant was found in violation of State Standards from the standpoint of BOD, suspended solids and bacteriological effluent discharge.

Federal Correctional Institution STP

This plant at a Federal prison is operated by the Department of Justice and discharges sewage effluent to Bear Creek. The facilities include an Imhoff tank and trickling filter; however, no secondary settling or chlorination is provided. Project sampling data estimated plant efficiency for BOD removal at 71 percent resulting in daily loading of 50 pounds. Plant efficiency for suspended solids reduction was estimated to be 72 percent, resulting in daily loading to the stream of 40 pounds. The plant effluent was in violation of State Standards regarding BOD, suspended solids and coliform.

Town of Evergren STP

M. A. Bauer

This trickling filter plant provides treatment for sewage from about 700 persons during the winter, and several times that figure during the summer. Project sampling data indicated plant efficiencies during June of 69 percent for BOD reduction, and 79 percent for suspended solids reduction. Daily loading to Bear Creek was estimated to be 35 pounds of BOD and 50 pounds of suspended solids. Although chlorination facilities were provided at this plant, they have never been used. The plant effluent was found to be in violation of State Standards for BOD, suspended solids, settleable solids and coliform.

Domestic and Industrial Loading

In Tables V and VI estimated BOD and TSS loadings are shown for four sewage treatment plants which receive significant amounts of industrial wastes.

(Tables V and VI are as follows:)

TABLE V

SUMMARY OF MUNICIPAL TREATMENT PLANTS WITH SIGNIFICANT INDUSTRIAL WASTES - BOD

Location	Population Served	Est. Daily Domestic Flow M.G.	Est. Daily Industrial Flow M.G.	Est. Total Daily Flow M.G.	Domestic Per Capita Flow Gal/Cap/Day	Domestic per Capita BOD Loading Lb/cap/Day	Est. Daily Domestic BOD Loading Lbs	Est. Daily Industrial BOD Loading Lbs	Est. Total BOD Loading Lbs	Influent BOD Mg/1	Effluent BOD Mg/1	Present Plant Efficiency %	Est. Total Daily BOD Loading to Stream Lbs
Clear Creek Valley District	7,000	1.19	0.30(a)	1.49(a)	170(b)	0.16	1,120	4,000(a)	5,120(a)	865(d)	285(d)	67	1,690(a)
Denver Northside	600,000	51.00	21.53(a)	72.53(a)	85	0.16	96,000	85,000(a)	181,000(a)	299(e)	174(e)	42	105,000(a)
Golden	8,000	1.20	1.50	2.70	150(c)	0.19(c)	1,500	14,400	15,900	750(e)	30(e)	96	636
North Washington District	12,000	1.15	0.35(a)	1.50(a)	96	0.16	1,920	9,840(a)	11,760(a)	1,150(d)	435(d)	62	4,460(a)

(a) Industrial flows and loading based on a 5-day week.
(b) High per capita flows likely due to ground water infiltration into sewers.
(c) Domestic sewers are combined, causing higher per capita flows and BOD loading.
(d) Obtained from Project sampling program, based on 8-hour daytime composites.
(e) Obtained from STP records, based on 24-hour composites.

TABLE VI

SUMMARY OF MUNICIPAL TREATMENT PLANTS WITH SIGNIFICANT INDUSTRIAL WASTES - TSS

Location	Population Served	Est. Daily Domestic Flow	Est. Daily Industrial Flow	Est. Total Daily Flow	Domestic Per Capita Flow	Domestic Per Capita TSS Loading	Est. Daily Domestic TSS Loading	Est. Daily Industrial TSS Loading	Est. Total TSS Loading	Influent TSS	Effluent TSS	Present Plant Efficiency	Est. Total Daily Loading to Stream
		M.G.	M.G.	M.G.	Gal/Cap/ Day	Lb/Cap/ Day	Lbs	Lbs	Lbs	Mg/l	Mg/l	%	Lbs
Clear Creek Valley District	7,000	1.19	0.30	1.49(a)	170(b)	0.200	1,400	2,000(a)	3,400(a)	738(d)	117(d)	84	545(a)
Denver Northside	600,000	51.00	21.53	72.53(a)	85	0.200	120,000	108,000(a)	228,000(a)	378(e)	96(e)	75	57,000(a)
Golden	8,000	1.20	1.50	2.70	150(c)	0.200	1,600	2,700	4,300	182(e)	20(e)	89	475
North Washington	12,000	1.15	0.35	1.50(a)	96	0.200	2,400	11,480(a)	13,880(a)	1,280(d)	360(d)	72	3,900(a)

(a) Industrial flows and loading based on a 5-day week.
(b) High per capita flows likely due to ground water infiltration into sewers.
(c) Domestic sewers combined, causing higher per capita flows.
(d) Obtained from Project sampling program, based on 6-hour daytime composites.
(e) Obtained from STP records, based on 24-hour composites.

M. A. Bauer

A large majority of industries that discharge their wastes to these sewage treatment plants operates for a 5-day period each week. For this reason the data are based on a 5-day week, since this period represents the most severe conditions in terms of industrial contributions. The data regarding industrial loading for these plants were obtained from treatment plant records, engineering studies and industrial plant surveys. The Adolph Coors Company Brewery operates throughout the entire week; therefore, the data for Golden is presented in terms of a 7-day week.

Inasmuch as the factors involved in the determination of pollutional loading vary widely, these treatment plants are described below.

City of Golden Sewage Treatment Plant

About 8,000 persons in the City of Golden are served under contractual agreement by this sewage treatment plant, which is owned and operated by the Adolph Coors Company. The sewers in Golden are predominantly combined, and data from the plant indicates the domestic BOD loading to be 0.19 pounds per capita per day. The treatment plant, which provides secondary treatment prior to discharge into Clear Creek, also processes industrial waste from the Adolph Coors Brewery. According to treatment plant records, the average daily loading is shown below:

	#BOD	#Suspended Solids
Brewery	14,400	2,700
Domestic	1,500	1,400
Total	15,900	4,100

This company has been successful in reducing wastes, particularly solids, within the manufacturing process. The treatment provided consists essentially of primary settling, mechanical aeration, secondary settling and removal of dewatered sludge to a company-owned landfill. A well equipped laboratory provides an excellent record of performance. These plant records indicate that the sewage treatment plant has provided a high degree of both BOD and solids removal during the calendar year 1964. Based upon a series of 24-hour composites obtained and analyzed by plant personnel during late 1963 and early 1964, the effluent quality averaged 640 pounds of BOD and 475 pounds of suspended solids for a plant efficiency of 96 and 89 percent. The Coors Company are commended for their concern with water pollution and the measures that they have taken to provide successful treatment for a highly organic waste.

North Washington Water and Sanitation District

This District operates a sewage treatment plant which serves a population of about 12,000 persons and receives industrial wastes from four meat packing plants. These industries include National Foods, which slaughters and provides packing and rendering for an average of 400 cattle daily; Litvak Meat Company, which slaughters and provides rendering for an average of 250 cattle daily; Rio Grande Packing Company, which slaughters an average of 145 cattle daily; and Altberger Company, which slaughters an average of 25 cattle daily. These plants, with the exception of the Altberger facility, provide some degree of in-plant pre-treatment in order to remove paunch manure, blood, grease, and a portion of solid waste prior to the final discharge into the District's sanitary sewers. The Altberger plant disposes of all process waste in the District sewerage facilities.

Factors of 12 pounds of BOD and 14 pounds of TSS per animal were used (7) (8) (9) to estimate the pounds of BOD and TSS discharged to the District plant from industrial sources. The 11,760 pounds of BOD received daily at the District plant, including domestic wastes, is somewhat less than the total of 12,625 pounds indicated by the Denver Metro Engineers in 1962 (6). Project sampling data indicated a plant efficiency of 62 percent for BOD removal and 72 percent for TSS removal. The daily loading to the stream is estimated to be 4,460 pounds of BOD and 3,900 pounds of TSS.

Clear Creek Valley Water and Sanitation District

This District's sewage treatment plant receives domestic wastes from about 7,000 persons and industrial waste from the Sigman Meat Company, Inc. The packinghouse operation includes beef and slaughtered hogs. The hog carcasses are delivered to the plant for processing of smoked and cured meats. The blood and renderable products are collected daily and sold to the Denver Rendering Company.

In December 1962 the consulting firm of Kirkham, Michael and Associates prepared a report for the Sigman Company concerning process wastes. At that time the following data were obtained for the plant effluent to the District plant for a 5-day week: 3,570 pounds of BOD per day, 1,690 pounds of TSS per day, and 1,590 pounds of volatile suspended solids per day. Present loading from this source is estimated at 4,000 pounds of BOD and 2,000 pounds of TSS daily. Combined domestic and industrial loading to the District plant is estimated to be 5,100 pounds of BOD and 3,400 pounds of TSS daily. Project sampling data indicated a plant efficiency of 67 percent for BOD removal and 84 percent for TSS removal. The daily loading to the stream is estimated to be 1,700 pounds of BOD and 550 pounds of TSS.

Denver Northside Sewage Treatment Plant

This facility is the largest treatment works in the Metropolitan Area. Although originally designed as a secondary facility, the plant now provides only primary treatment consisting of pre-aeration basins, primary settlir chambers, sludge digesters, and sludge beds. The original magnetite filter basins, which were intended to provide secondary treatment, have been converted for use as chlorination detention chambers. In 1964, it is estimated that 600,000 persons were served by this plant. Based upon data obtained from plant records for the period December 1, 1963-November 30, 1964, the average flow into the plant was 70.05 mgd. Daily 24-hour composite samples collected and analyzed by plant personnel indicated an average influent BOD of 278 mg/1 and an average effluent BOD of 151 mg/1.

On the basis of these data, the plant received an average loading of 163,000 pounds of BOD daily. Based on the average figure of 85 gallons per capita per day derived from the Project survey of plants in the Metropolitan Denver area, and 0.160 pounds of BOD per capita, the domestic contribution to this plant on an average daily basis would be 51 mgd and 96,000 pounds of BOD per day. The remainder of the total flow and loading, which is estimated as 19 mgd and 67,000 pounds, can be attributed to industrial sources. However, since the majority of the industrial contribution is received at the plant during a 5-day period, the daily flow and loading data obtained from the plant has been examined on a weekday (Monday through Friday) basis.

During the period December 1, 1963, to November 30, 1964, there was a total of 261 weekdays. The average flow was 72.53 mgd during this time. The influent BOD averaged 299 mg/1 and the effluent BOD averaged 174 mg/1. From this information, the average daily loading received in the plant during the 5-day week was 181,000 pounds of BOD. Thus, the industrial flow averaged 21.5 mgd and 85,000 pounds of BOD per day during this 5-day period.

M. A. Bauer

The influent TSS averaged 378 mg/l and the effluent TSS averaged 96 mg/l. The average daily load to the plant during the 5-day week was 228,000 pounds of TSS. Based on plant data, daily loading to the river was estimated at 105,000 pounds of BOD, and 57,000 pounds of suspended solids. Project sampling data indicated that the mean coliform density of the chlorinated effluent was less than 100,000 organisms per ml.

Due to insufficient digestor capacity, partially digested sludge and sludge supernatant have been discharged directly to the South Platte River in the past. Project personnel were informed that this practice was discontinued in August 1964, and that the supernatant is now being recycled to the influent lines for additional treatment.

Loading to the South Platte River and Tributaries

Table VII contains a summary of flow data, BOD, TSS and coliform loading from municipal sewage treatment plants to the South Platte River and each of the principal tributaries in the Metropolitan Area.

(Table VII is as follows:)

TABLE VII

SUMMARY OF MUNICIPAL SEWAGE TREATMENT PLANT LOADING TO STREAMS

Stream	Plant Location	River Mile	Estimated Average Daily Flow MGD	BOD Discharged to Stream Lbs/day	Total Susp. Sol. Discharged to Stream Lbs/day	Total Coliform MPN/100 ml
Bear Creek		320.9				
	Evergreen	320.9/19.3	0.065	35	50	3,300,000
	Federal Correctional Institution	320.9/5.5	0.060	50	40	1,600,000
South Platte River	Littleton	323.5	2.60	715	780	5,400,000
	Englewood	319.7	4.50	1,350	1,460	3,700,000
	S. Lakewood	314.1	0.55	175	310	160,000
	Denver - Northside	308.8	72.53(a)	105,000(a)	57,000(a)	30,000
	North Washington	305.5	1.50(a)	4,460(a)	3,900(a)	45,000,000
	Thornton	303.5	2.60	3,535	4,460	36,000,000
	South Adams	301.2	1.50	255	640	5,200
	Brighton	289.5	0.65	45	170	520
Sand Creek		306.8				
	Buckley Air Station	306.8/11.9	0.05	9	20	
	Fitzsimons Hospital	306.8/6.8	0.47	70	150	5,600
	Aurora - Sand Creek	306.8/6.8	0.66	100	250	18
	Aurora - Westerly	306.8/5.5	3.10	1,365	2,030	4,200,000
	Denver - Eastside	306.8/4.7	1.40	2,050	1,040	140,000
Clear Creek		305.5				
	Golden	305.5/15.5	2.70	636	450	790,000
	Northwest Lakewood	305.5/10.2	1.90	2,780	2,010	6,600,000
	Fruitdale	305.5/10.0	0.20	200	110	9,700,000
	Wheatridge	305.5/7.3	1.80	1,210	980	1,900,000
	Clear Creek Valley	305.5/7.0	1.50(a)	1,690(a)	545(a)	8,300,000
	Arvada	305.5/6.2	3.50	4,755	5,760	7,600,000
	Westminster	305.5/3.6	1.30	3,025	2,160	37,000,000
	Baker	305.5/3.0	1.50	1,645	1,390	9,700,000

(a) Based on a 5-day week. (b) Not including bypass.

Where significant industrial wastes are present, the data, with the exception of the Golden sewage treatment plant, is presented in terms of a 5-day week.

The total daily loadings to Basin streams in the Metropolitan Area are estimated to be 135,000 pounds of BOD and 86,000 pounds of TSS. The major source of pollution, accounting for nearly 78 percent of the total BOD load and 66 percent of the total TSS load, is the Denver Northside plant, which presently has primary treatment facilities. Sewage treatment plants serving Arvada, Aurora (Westerly), Baker District, Clear Creek District, Denver Eastside, North Washington District, Northwest Lakewood District, Thornton, and Westminster together contribute 18 percent of the total BOD load and 27 percent of the total TSS load. The average daily flow at each of these plants exceeds the present plant capacity and four of these facilities are providing only primary treatment.

V. DISCUSSION

Future Operation of Metropolitan Denver Sewage Disposal District No. 1

The Metropolitan Denver Sewage Disposal District

No. 1 waste treatment plant, which is scheduled to commence operation prior to January 1, 1967, should provide substantial pollution abatement for Basin streams in the Metro Denver Area. In addition, these facilities will offer the advantages of a centralized location and an economical means of providing adequate sewage treatment. The design of the District plant has sufficient flexibility to allow for expansion of both primary and secondary treatment facilities in several stages. Denver Metro Engineers estimate that expansion of the District plant will be required in 1981 for primary treatment facilities and in 1982 for the secondary treatment facilities (11). If the Clear Creek secondary treatment plants are abandoned, these expansion dates are estimated to be 1974 for primary treatment and 1980 for secondary treatment.

The present Denver Northside treatment plant has been expanded and renovated. According to design criteria published by MDSDD#1 in February 1964, the revised Denver Northside plant will be expected to receive a BOD loading of 207,000 pounds daily with a removal of 35 percent or 72,500 pounds of BOD (12). The remaining 134,500 pounds of BOD will receive secondary treatment at the Metro District plant. The Metro District primary treatment works are designed to remove 35 percent of 63,500 pounds of

BOD from wastes received daily from the Clear Creek and Sand Creek interceptors. The discharge from these primary treatment units will be routed to the secondary treatment facilities at the District plant. According to the design criteria mentioned above, the Metro District secondary treatment works are capable of handling 166,350 pounds of BOD daily. The following table is presented to clarify the BOD loadings described above.

	Primary Treatment		Secondary Treatment	
	In (lbs)	Out (lbs)	In (lbs)	Out (lbs)
Denver Northside Plant	207,000	134,500	--	--
MDSDD#1 Plant	63,000	41,300	175,800	27,000 (90% removal)
Totals	270,000	175,800	175,800	27,000

Data obtained by Project personnel from plant records at the Denver Northside works for the period December 1963 to November 1964 indicated the average daily influent loading on a 5-day week basis was 181,000 pounds of BOD. These data also revealed that during the months of July and October 1963, 215,000 and 226,000 pounds respectively of BOD was the average daily contribution to this plant in terms of a 5-day week. These values are already in excess of the daily BOD loading of 207,000 pounds previously indicated as a design factor for this plant. It is likely that the recirculation of sludge supernatant to the plant influent line affected the loading for October; however, this condition did not exist in July. It is also significant that total BOD loading to this plant on a 5-day week basis has increased from about 140,000 pounds per day in 1960 according to Metro Denver Engineers (3) to an estimated 181,000 pounds per day in 1964. Additional loading to the Northside plant will be realized by diversion to the Denver sanitary sewers of industrial and commercial wastes now discharging directly to the streams.

On the basis of the conditions outlined above and the possibility that the Clear Creek secondary treatment plants will cease to operate within a few years, it is likely that expansion of secondary treatment facilities at the Metro District plant will be necessary earlier than the anticipated date of 1980.

Operation of Municipal Waste Treatment Plants

M. A. Bauer

Three components of sound operation for any waste treatment plant are 1) personnel, 2) laboratory control, and 3) records. Sufficient personnel with skills commensurate to the size and complexity of the plant are required to obtain the degree of treatment provided by the plant design and to maintain and protect the community's investment in the physical plant. In order to measure the degree of treatment being obtained and to locate existing or impending operational troubles, adequate laboratory control must be exercised. The third operating component, keeping records, is necessary for proof of performance and for use in planning and justifying future plant needs and expansions.

"Recommendations for Minimum Personnel, Laboratory Control, and Records for Municipal Waste Treatment Works," adopted in 1963 by the Conference of State Sanitary Engineers and published in cooperation with the Department of Health, Education, and Welfare, outlines by plant capacity the minimum requirements for each component in order to provide adequate operation control (13).

During the Project study of municipal waste treatment plants in the Metropolitan Denver Area, each plant was evaluated with respect to these factors. Only four plants were found to be in substantial conformance with these Minimum Recommendations. These plants are Fitzsimons, Adolph Coors (Golden), Aurora (Westerly), and Denver Northside. The remaining 19 plants provide some degree of laboratory control, minimum personnel requirements and provisions for record keeping; however, considerable improvement can be obtained for relatively little additional expense. It is proposed that the provisions of "Recommendations for Minimum Personnel, Laboratory Control and Records" (13) be adopted for all municipal sewage treatment plants in Colorado.

Pollution Abatement

The schedule contained in Table VIII is recommended to provide pollution abatement for municipal sewage treatment plants in the Metropolitan Denver Area based upon existing State law and regulations.

(Table VIII is as follows:)

TABLE VIII

POLLUTION ABATEMENT SCHEDULE

Plant Name	Design capa-city (mgd)	Avg. Flow (mgd)	Effluent Quality BOD (Mg/1)	Effluent Quality VSS (Mg/1)	Effluent Quality Coliform Density (MPN/100 ml)	Recommendations	Suggested Abatement Schedule
Member Plants of MDSDD#1							
Baker W & S District	1.0	1.5	150	85	$9.7\text{x}10^6$	Divert sewage to MDSDD#1 and provide adequate treatment including chlorination for any sewage discharged to Clear Creek.	Jan. 1967
City of Westminster	1.25	1.3	335	155	$3.7\text{x}10^7$	Arrange for an engineering study to evaluate operation procedures and improve plant efficiency; and, Divert sewage to MDSDD#1 and provide adequate treatment including chlorination for any sewage discharged to Clear Creek.	Immediately Jan. 1967
City of Arvada	0.75	3.5	210	205	$7.6\text{x}10^6$(e)	Divert sewage to MDSDD#1 and provide adequate treatment including chlorination for any sewage discharged to Clear Creek.	Jan. 1967
Wheatridge	1.75	1.80	95	56	$1.7\text{x}10^6$(a)	Divert sewage to MDSDD#1 and provide adequate treatment including chlorination for any sewage discharged to Clear Creek.	Jan. 1967
Northwest Lakewood Sanitation District	1.8	1.9	215	106	$6.6\text{x}10^6$	Divert sewage to MDSDD#1	Jan. 1967

Table VIII (Continued)
Pollution Abatement Schedule

Plant Name	Design capacity (mgd)	Avg. Flow (mgd)	Effluent Quality BOD (mg/1)	Effluent Quality VSS (Mg/1)	Effluent Quality Coliform Density (MPN/100 ml)	Recommendations	Suggested Abatement Schedule
Member Plants of MDSDD#1							
North Washington W & S District	1.0	1.4	435	309	$4.5x10^7$	Divert sewage to MDSDD#1 and provide adequate treatment including chlorination for any sewage discharged to Clear Creek.	Jan. 1967
City of Denver (Eastside Plant)	2.0	1.5	205	85	$1.4x10^5$	Divert sewage to MDSDD#1	Jan. 1967
City of Denver (Northside Plant)	85	70.5(b)	151(b)	66(b)	$3.0x10^4$	Divert effluent to MDSDD#1	Jan. 1967
Plants not presently Members of MDSDD#1:							
City of Brighton	2.0	0.65	12	24	$5.2x10^2$	NONE	---
South Adams County Sanitation District	2.5	1.5	26	43	$5.2x10^3$	NONE	---
* City of Thornton	1.9	2.6	205	175	$3.6x10^7$	Revise and expand plant facilities to provide adequate treatment, including chlorination for present and future loadings (c)	Jan. 1967
Clear Creek Valley Sanitation District	0.85	1.4	285	100	$8.3x10^6$	Revise and expand plant facilities to provide adequate treatment including chlorination for present and future loadings (c)	Jan. 1967

*Thornton should be deleted from this category and added to "Member Plants of MDSDD#1."

Table VIII (Continued)
Pollution Abatement Schedule

Plant Name	Design Capacity (mgd)	Avg. Flow (mgd)	Effluent Quality BOD (mg/1)	Effluent Quality VSS (mg/1)	Effluent Quality Coliform Density (MPN/100 ml)	Recommendations	Suggested Abatement Schedule
Plants not presently Members of MDSDD#1:							
Fruitdale Sanitation District	2400 (d) persons	0.2 (winter) 1.0 (summer)	110	60	$5.9x10^7$(a)	Revise and expand plant facilities to provide adequate treatment including chlorination for present and future loadings (c)	Jan. 1967
Adolph Coors Co.	4.5	2.7	30(b)	35(b)	$7.9x10^5$(a)	Complete planned expansion and provide adequate chlorination.	Jan. 1967
City of Aurora (Westerly)	3.1	2.5	64	61	$4.2x10^6$	Complete planned diversion of flow to new (Sand Creek) plant and provide adequate chlorination (c)	Jan. 1967
City of Aurora (Sand Creek)	1.0	0.66	20	32	$<1x8x10^1$	Complete planned expansion of plant facilities to process flow diverted from Westerly plant (c)	Jan. 1967
Fitzsimons Army Hospital	.90	0.47	27(b)	36(b)	$2.0x10^4$	NONE	---
Buckley Air Station	1.5	0.05	23	27	$7.9x10^4$	Provide adequate chlorination facilities.	Jan. 1967
South Lakewood Sanitation District	0.6	0.6	52	64	$1.6x10^5$(a)	Complete engineering study and planned expansions to include adequate chlorination.	Jan. 1967
City of Englewood	8.0	4.5	48	39	$3.7x10^6$(a)	Complete engineering study to determine present and future needs including adequate chlorination.	Jan. 1967

Table VIII (Continued)

Pollution Abatement Schedule

	Design		Effluent Quality				
Plant Name	Capacity (mgd)	Avg. Flow (mgd)	BOD (mg/1)	VSS (mg/1)	Coliform Density (MPN/100 ml)	Recommendations	Suggested Abatement Schedule
Plants not presently Members of MDSDD#1:							
City of Littleton	2.75	2.6	43	33	5.4×10^6(a)	Complete planned engineering study to determine present and future needs including adequate chlorination.	Jan. 1967
Federal Correctional Institution	0.6	0.06	165	55	2.6×10^6(a)	Discharge all wastes to the Lakehurst Sanitation District.	Jan. 1967
Town of Evergreen	0.25	0.065	80	80	3.3×10^6	Revise or expand plant facilities to provide adequate treatment including adequate chlorination for present and future loadings.	Jan. 1967

(a) Data furnished by Colorado State Department of Public Health.
(b) Data furnished by plant operator.
(c) Has requested feasibility estimate from MDSDD#1.
(d) Limited by digestor capacity.
(e) Not including bypassed sewage.

M. A. Bauer

In determining whether or not there is a present need for pollution abatement at a specific plant, an examination of several factors is required. Such considerations include: 1) the waste load reductions necessary to provide the desired water quality in the receiving water; and 2) the performance of the treatment plant in terms of operational efficiency. These factors have been examined for each plant in terms of the existing State regulations and laws governing sewage effluent discharges. That portion of current statutes which pertains to the effluent from sewerage systems is outlined in Appendix A of this report.

It is not intended, however, to define permissible loading from a municipal waste treatment plant discharge to a receiving stream solely upon that which is now permitted under present State standards. The capacity of the stream to absorb wastes from a single municipal waste plant effluent must be considered in the light of other waste discharges both above and below the plant and the pattern of flow and diversions associated with the receiving water. In the final analysis each waste discharge permitted in the Basin will have to conform to criteria considered necessary to provide water quality in the streams according to the maximum beneficial use. At this time such water quality criteria has not been established and, therefore, the present State Standards have been employed only as a general guide.

Those municipalities and districts which are presently affiliated with MDSDD#1 are considered to be committed to an effective course of pollution abatement. These include Arvada, Baker District, Denver, North Washington District, Northwest Lakewood District, Westminster, Wheatridge and Thornton. The facilities for MDSDD#1 are presently under construction and current estimates indicate operation of the treatment works will commence prior to January 1, 1967. The Adolph Coors Company, which operates the sewage treatment plant in Golden, is committed to an effective program for pollution abatement. This industry's wastes are in conformity with State waste effluent standards, except during periods of peak flows. Expansion of plant facilities is planned during 1966. The completion date proposed for those plants at which major revisions or improvements have been recommended is also January 1, 1967.

It has been recommended that steps be undertaken by January 1, 1967, to provide adequate chlorination facilities in those plants which will continue to discharge wastewater to Basin streams after construction of the MDSDD#1 treatment facilities has been completed.

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APPENDIX A

COLORADO STATE DEPARTMENT OF PUBLIC HEALTH

DIVISION OF SANITATION

Water and Sewage Laws (Health Department)

The following items are taken from the laws governing the Colorado State Department of Public Health. These items consist of pertinent extracts contained in Chapter 66 of the Colorado Revised Statutes, 1953, together with the amendments as enacted by the General Assembly in 1955 and 1959. These particular items deal with the minimum standards allowable for water supplies used for human consumption and domestic sewage and trade wastes. They also deal with the standards and hearing procedures for the control of domestic sewage.

66-1-7. POWERS AND DUTIES OF THE STATE DEPARTMENT OF PUBLIC HEALTH

The State Department of Public Health shall have and exercise, in addition to all other powers and duties imposed upon it by law, the following powers and duties:

M. A. Bauer

. . . .

(5) To establish and enforce minimum general sanitary standards as to the quality of water supplied to the public and as to the quality of the effluent of sewerage systems and trade wastes discharged upon the land or into the surface or ground waters, and as to the quaility of fertilizer derived from excreta of human beings or from the sludge of sewage disposal plants; and to advise with municipalities, utilities, institutions, organizations and individuals, concerning the methods or processes believed best suited to provide the protection or purification of water and the treatment of sewage and trade wastes to meet such minimum general sanitary standards:

. . . .

(8) To establish, maintain and approve chemical, bacteriological and biological laboratories, and to conduct such laboratory investigations and examinations as it may deem necessary or proper for the protection of the public health;

(9) To make, approve and establish standards for diagnostic tests by chemical, bacteriological and biological laboratories, and to require such laboratories to conform thereto; and to prepare, distribute and require the completion of forms or certificates with respect thereto:

. . . .

(18) (Subsection revised by Amendment enacted by the General Assembly, 1955)

The phrase "minimum general sanitary standards" as used in this section shall mean the minimum standards reasonably consistent with protection of the public health, and in the case of minimum general sanitary standards as to the quality of water supplied to the public, the same shall in no event be less than the drinking water standards of the United States Public Health Service. The word "standards" as used in this section shall mean standards reasonably designed to promote and protect the public health.

(19) (Subsection added by the General Assembly, 1959)

(a) To enforce the public policy of the State of Colorado with reference to the pollution of waters of the State by human excreta as herein expressed, it is hereby declared that the health, safety, and welfare of the inhabitants of the State of Colorado require that the streams, lakes, and other waters of the State be kept free of pollution by human wastes, and it is therefore declared to be the public policy of this State that no discharge which contains human excreta shall be permitted to flow in the streams, lakes, or other waters of this State, unless such discharge shall comply with all standards of the State Board of Health adopted pursuant to law; and in addition thereto the following standards shall apply:

(b) The number of coliform count in such discharge shall not average more than one thousand per millimeter, such average being based upon a total of not less than four samples taken at the rate of at least one sample per day over a period of four consecutive days.

(c) Minimum standards for effluent from sewerage systems shall be not more than five-tenths milliliter per liter for settleable organic matter, shall be not more than seventy-five parts per million by weight for suspended organic matter, and shall be not more than fifty parts per million for the combined suspended and dissolved organic matter when measured in terms of five-day twenty-degree Centigrade biochemical oxygen demand test.

(d) The methods of examination employed to determine compliance with any one of the above standards shall be those set forth in Standard Methods for the Examination of Water Sewage and Industrial Wastes, Tenth Edition, prepared and published jointly by the American Public Health Association, the Federation of Sewage and

Industrial Waste Associations, and the American Water Works Association, New York, 1955.

(e) In addition to all other powers, duties and means of enforcement of the above stated standards, it shall be the duty of the Department of Public Health to investigate and determine the facts with reference to the discharge or disposition of sewage or any other matter containing, or having had as a component part thereof, human excreta in any stream, lake or body of water within the State, upon its own initiative or upon the filing with such department of a verified petition as herein provided. Said petition may be filed with the department by the governing body of any municipality, or any county, or any county or district health department, or any State agency or any twenty-five residents of an county complaining of pollution resulting from any one source which pollution exists in the county of residence of the petitioners, alleging that such discharge or other disposition in such stream, lake or other body of water is in violation of any law or of any rule or regulation of the State Board of Health, and identifying the person, or persons, instrumentalities or agencies responsible for such discharge or other disposition.

(f) Such study, investigation or survey may include engineering studies and bacteriological, biological and chemical analyses of the effluent or other matter so discharged or disposed of in said waters to the extent that they may be necessary to determine the facts and to establish ways and means of eliminating such violations of law, rules or regulations as may be found to exist. The director shall, within a reasonable time, make tentative findings in writing which shall set forth the matters investigated and shall specify the violations, if any, found to have occurred, and the extent and degree thereof, together with a tentative determination of the person or persons, instrumentalities or agencies responsible therefor, and also the methods of eliminating the source or cause of the violation. If no violation is found the director shall forthwith order the proceedings dismissed, in which case the petitioners, if any, may have the director's findings and order of dismissal reviewed as provided in section 66-1-13. If one or more violations are found, said tentative findings shall fix a time and place for a hearing before the State Board of Health which shall be not less than thirty days after issuance and service as herein provided of said tentative findings. A copy of such tentative findings shall be served by registered or certified mail upon each person, agency or instrumentality alleged by said petition or determined by said findings to be responsible therefor and upon at least one of the initiators of the petition, if any; or service may be made in the same manner as is provided by the rules of civil procedure for personal service of process. The hearing by the Board shall be held as is provided by subsection (8) of section 66-1-8.

(g) Plans, specifications, and other related data pertaining to the proposed construction of any and all publicly or privately owned community water or sewage treatment facilities, not including industrial plants, shall be submitted to the State Department of Public Health for review of sanitary engineering features prior to the construction of such facilities.

(h) The Colorado State Department of Public Health is hereby delegated the responsibility of establishing and maintaining a quality testing program on the waters of the State. Such testing program shall be for the purpose of determining adequacy of abatement measures, developing programs for abatement, and ascertaining changes, natural and otherwise, in water quality.

(i) The examination for water quality shall include such physical, chemical, biological, and radiological or other tests as may be necessary in order to be useful in determining the effects upon water quality employed for possible recreational, industrial, agricultural, fish and wildlife, and municipal uses.

(j) The Colorado State Department of Public Health, in the exercise of these duties and powers shall advise, consult, and cooperate with the cities, sewer districts, intercounty regional planning agencies, other agencies of the State, the Federal Government, and other States and interstate agencies, and industries, in furtherance of the purposes of this section.

66-1-8. POWERS AND DUTIES OF THE STATE BOARD OF HEALTH

In addition to all other powers and duties conferred and imposed upon the State Board of Health by the provisions of this article, the Board shall have and exercise the following specific powers and duties:

. . . .

(5) To hold hearings, administer oaths, subpoena witnesses and take testimony in all matters relating to the exercise and performance of the powers and duties vested in or imposed upon the State Board of Health.

. . . .

(8) (Subsection added by the General Assembly, 1955)

Upon the issuance of a tentative finding as provided by section 66-1-7 (19), the State Board of Health shall, on the day set for hearing by said finding or any day to which the same may be continued, proceed to hear the matter. The Board shall afford a fair and full opportunity to all parties in interest to be heard in person or by counsel as to the correctness of the tentative findings of the director, and said board shall then make its findings. If the Board finds that the tentative findings of the director with respect to any violation of law or of the rules and regulations of the Board is substantially correct, and if the person, persons, agencies or instrumentalities responsible for such violations have been before the Board, then the Board shall direct such person, persons, agencies or instrumentalities to abate the violations. If, however, it appears that the person, persons, agencies or instrumentalities responsible for the violations have not been before the Board, then the hearing shall be continued until such time as jurisdiction over such parties is acquired by service upon them in the manner provided in section 66-1-7(19) of a copy of the director's tentative findings and of the board's determination that the presence of such person, persons, agencies of instrumentalities is necessary to a complete determination of the procedure. Every such person, persons, agencies or instrumentalities shall be given full and fair opportunity to be heard, and the hearing to which the proceeding shall be continued shall be de novo, unless the new party or parties, having been properly served, shall fail to appear.

A copy of the decision of the Board shall be promptly served upon each party in interest by registered mail and shall set forth a reasonable time as determined by the Board for the abatement of any violations found to exist, which reasonable time may at the discretion of the Board be extended from time to time for good cause shown by the party responsible for such abatement.

All findings of violations, and orders for abatement thereof, must be made by a vote of a majority of the members of the State Board of Health. All such decisions of the Board shall be subject to judicial review as provided in section 66-1-13, and all orders of the Board issued hereunder may be enforced as any other standard rule, regulations or order of the Board.

66-1-13. JUDICIAL REVIEW OF DECISIONS. Any person aggrieved by a decision of the Board or the Director and affected thereby shall be entitled to judicial review by filing in the district court of the county of his residence, or of the city and county of Denver, within ninety days

M. A. Bauer

after the public announcement of the decision, and appropriate action requesting such review. The court may make any interested person a party to the action. The review shall be conducted by the court without a jury and shall be confined to the record, if a complete record is presented, except that in cases of alleged irregularities in the record or in the procedure before the Board or the division of administration, testimony may be taken in the court. The court may affirm the decision or may reverse or modify it if the substantial rights of the appellant have been prejudiced as a result of the findings and decisions of the Board being:

(1) Contrary to constitutional rights or privileges; or

(2) In excess of the statutory authority or jurisdiction of the Board or the Director, or affected by any error of law; or

(3) Made or promulgated upon unlawful procedure; or

(4) Unsupported by substantial evidence in view of the entire record as submitted; or

(5) Arbitrary or capricious.

Any party may have a review of the final judgment or decision of the district court by writ of error

M. A. Bauer

to the Supreme Court.

* * *

M. A. Bauer

GROUND-WATER POLLUTION
in the
SOUTH PLATTE RIVER VALLEY
BETWEEN DENVER AND BRIGHTON, COLORADO

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Water Supply and Pollution Control
South Platte River Basin Project
Denver, Colorado

December 1965

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SOUTH PLATTE RIVER BASIN PROJECT

U.S. Public Health Service

Background and Objectives

On July 18, 1963, the Governor of Colorado requested the Secretary of Health, Education, and Welfare to assist the State in determining sources of pollution and quality of waters of the South Platte River Basin within the State of Colorado.

The First Session of the Conference in the Matter of Pollution of the South Platte River Basin was held in Denver, Colorado, on October 29, 1963, under the provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 466g). It was established at this conference that a study would be undertaken by facilities of the United States Public Health Service. Findings and recommendations from this study would lead to a program of pollution abatement to be developed jointly by the South Platte River Basin Project, Public Health Service, and the Colorado State Department of Public Health.

The long-range goals and objectives of the Project are as follows:

1. Determine the legitimate water uses and locate the sources of pollution having an adverse effect on those uses.
2. Through field investigations determine the physical, chemical and biological responses of the river to pollution and evaluate the previously located sources of pollution with respect to the conditions in the river.
3. Compute the waste load reductions necessary to obtain desired water quality and recommend water quality control measures needed to effect the desired waste load reductions.

Organization

The South Platte River Basin Project consists of engineering and associated professional and clerical personnel. The Project headquarters offices are located in downtown Denver and the laboratory has been established at the Colorado State Department of Public Health, Denver, Colorado. The Project is administratively attached to the Water Supply and Pollution Control Program of the Public Health Service, United States Department of Health, Education, and Welfare, Region VIII, Denver, Colorado.

ACKNOWLEDGMENTS

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Colorado State Department of Public Health, Engineering and Sanitation Division, Denver, Colorado.

Colorado Water Conservation Board, Denver, Colorado.

State Engineer of Colorado, Ground-Water Section, Denver, Colorado.

Colorado Public Utilities Commission, Denver, Colorado.

Colorado State University, Engineering Research Center, Fort Collins, Colorado.

Tri-County Health Department, Aurora, Colorado.

City of Brighton, Brighton, Colorado.

City of Thornton, Thornton, Colorado.

North Washington Water and Saniation District, Denver, Colorado.

Northwest Water Corporation, Denver, Colorado.

M. A. Bauer

South Adams Water and Sanitation District, Commerce City, Colorado.

Town and Country Mutual Water Company, Commerce City, Colorado.

U. S. Bureau of Reclamation, Region 7, Denver Development Office, Denver, Colorado.

U. S. Geological Survey, Water Resources Division, Branch of Ground Water, Denver, Colorado.

U. S. Department of Agriculture, Soil Conservation Service, Brighton, Colorado.

U. S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Denver, Colorado.

U. S. Army Engineer District, Omaha, Corps of Engineers, Omaha, Nebraska.

U. S. Department of Army, Rocky Mountain Arsenal, Denver, Colorado.

SUMMARY AND CONCLUSIONS

The fresh-water-bearing formations occurring in the South Platte River Valley between Denver and Brighton, Colorado, consist of the bedrock formations and the overlying valley-fill deposits. Water wells completed in the bedrock aquifers yield small to moderate amounts of good quality water in most of the area. The water-bearing characteristics of the valley-fill aquifer are very favorable for developing large water supplies from shallow wells located throughout much of the valley.

Over 1,076 wells currently withdraw water from the valley-fill aquifer. Approximately 15,500 acres of farm land are irrigated with this water. Withdrawals from irrigation wells were about 22,000 acre-feet in 1963 and comprised about 70 percent of the total ground-water pumpage. The valley-fill aquifer is the chief source of water for the majority of the public water systems. Withdrawals from shallow public supply wells continue to increase, averaging 7.1 million gallons per day (8,510 acre-feet per year) in 1964.

Over a period of years, discharges from the valley-fill aquifer are balanced by recharge. The chief source of recharge to the aquifer is from seepage derived from South Platte River water diverted to the irrigation ditches in the area. Approximately 50 percent of the river water diverted to the irrigation ditches enters the shallow aquifer.

Two incidents of ground-water contamination by gasoline spills or leakages have occurred. Portions of the shallow aquifer in these two localities most likely remain contaminated.

Much of the valley-fill aquifer in Sand Creek Valley is probably contaminated by petroleum wastes. In the Commerce City area, two public supply wells owned by Town & Country Mutual Water Company have been contaminated by hydrocarbons since 1957.

Alkyl benzene sulfonate (ABS) is found throughout most of the valley-fill aquifer. Most shallow public supply wells yield water containing significant concentrations of ABS. The principal source of ABS in the aquifer is sewage-laden recharge water from the South Platte River, Sand Creek and Clear Creek.

Nearly all bacteria are removed by infiltration through the saturated zone. However, residual bacteria may be found after travel over appreciable distances. Bacteriological data from two public water supplies adjacent to the South Platte River indicate fecal coliforms were present in the aquifer 300 feet from the river.

The principal source of nitrates in the shallow aquifer is fertilizer applied to irrigated farms. Feedlot operations and sewage-laden waters diverted from the river have also contributed nitrates to the aquifer. Highest nitrate concentrations generally occur in and near the irrigated lowland areas where nitrates commonly exceed 35 parts per million (ppm) and are as high as 90 ppm. Two public supply wells owned by the South Adams Water and Sanitation District yield water having nitrate concentrations of 50 parts per million. Nitrate concentrations of water from the City of Brighton's wells currently range from 55 to 72 ppm. Waters from these public supply wells contain nitrates in excess of 45 mg/1, the upper limit of the United States Public Health Service Drinking Water Standards, and is potentially dangerous when used for infant feeding. One case of infant methemoglobinemia in 1962 was attributed to the use of Brighton's well water.

M. A. Bauer

The shallow aquifer underlying approximately 12 square miles in the vicinity of the Rocky Mountain Arsenal has been severely contaminated by chemical wastes discharged into unlined holding ponds and First Creek prior to 1957. Contaminants known to be present in the shallow aquifer include chloride, fluoride, arsenic, chlorate, the herbicide 2, 4-D, and the pesticides aldrin and dieldrin. Severe damages to crops and ground-water supplies have resulted from the contamination. Contamination in the vicinity of the Rocky Mountain Arsenal will persist for many decades in the future, principally due to the relatively slow movement of ground-water in the heavily contaminated parts of the aquifer.

The possibility of Arsenal-contaminated ground-water moving directly into the City of Brighton's water well field is remote at this time. However, it is conceivable that the contaminated water could be induced directly to Brighton over a long period of time under circumstances of progressively increasing ground-water withdrawals immediately north of the contaminated zone.

Saline water from the shallow contaminated zone in the vicinity of the Arsenal has likely entered the underlying bedrock aquifers through at least three defective deep wells. However, the actual number of defective wells is unknown since relatively few of the 61 deep wells located in or near the contaminated shallow zone have been sampled since 1959.

RECOMMENDATIONS

The Colorado State Department of Public Health and other agencies as indicated below should undertake and implement the following measures:

A. In view of the shallow aquifer's great susceptibility to contamination, it is recommended that the following measures be taken to minimize pollution and contamination in the future:

   1. Seal settling ponds and ditches used for the treatment of industrial waste with an impermeable material.
   2. Provide municipal sewage treatment systems for the densely populated suburban localities, thereby eliminating existing septic tank discharges directly into the shallow aquifer.
   3. Construct linings in feedlot pens and areas

used for manure storage with an impermeable material and properly drain to prevent seepage directly into the aquifer. In addition, these waters should be adequately treated before discharging to a surface watercourse.

4. Improve the quality of waste water discharged to the South Platte River and its tributaries. Since a large part of flow in these streams consists of industrial and municipal effluents, and nearly all recharge to the aquifer originates from these surface flows, the chemical quality of ground-water will be influenced to a great extent by the character of wastes discharged to the streams.

B. In view of the possibility of large-scale petroleum contamination of the shallow aquifer in Sand Creek Valley and parts of the main valley, it is recommended that the following measures be taken:

1. Conduct a detailed investigation to determine the real extent of petroleum contamination and effects on public and domestic ground-water supplies.
2. Investigate effectiveness of methods for detecting leakage from pipelines, storage tanks and other facilities of the petroleum industries in the area.

C. In view of the probability that pollution of the valley-fill aquifer will persist for many decades in the future, public water systems in the area should consider replacing their shallow ground-water supplies with water from outside sources. Many of these public water systems are presently considering other sources of water and are engaged in negotiating for outside sources of water.

D. In view of the occurrence of significant and often excessive concentrations of nitrates in the aquifer and the large number of domestic wells in use, it is recommended that the following measures be taken:

1. Conduct periodic detailed field inventories of all domestic water wells in the area, and obtain and record the following information:
    a. Water sample for chemical analysis.
    b. Pertinent well information, including owner's name, location, driller's log, depth, perforated interval, casing size, and water level.
2. If excessive nitrates are found, the well user should be notified in writing as to the results of the chemical analysis and the hazards, especially to new-born babies, of using these

waters; another source of drinking water should be obtained.

E. In view of the possibility of continued expansion of the contaminated zone in the vicinity of Rocky Mountain Arsenal, well water monitoring programs of the Tri-County Health Department and Colorado State Department of Public Health, and the Arsenal, should be continued. It is recommended that the following additional measures be taken by the Colorado State Department of Public Health and the Rocky Mountain Arsenal:

1. Prevent large increases in ground-water withdrawals from the valley-fill aquifer in areas lying immediately outside of the contaminated zone.
2. Acquire approximately 12 additional sampling wells along and immediately outside of the east and west edges of the contaminated zone in Sections 2, 3, 12, 13, 24, 25, and 36 of T. 2 S., R. 67W., and in Sections 21, 27, 28, 34 and 35 of T. 2 S., R. 67 W. Water samples should be collected from these sampling wells at least once annually near the end of the irrigation pumping season, preferably during the last week of August or the first week of September.

3. Obtain samples from all deep wells located in or near the contaminated zone at least once annually for chemical analysis in order to detect possible contamination. All contaminated deep wells should be completely plugged with cement.

4. Laboratory analysis of water samples should include the determination of all contaminants known to be present in the contaminated zone.

F. In view of the continued high degree of saline contamination in most of the area underlying the Arsenal, it is recommended that the Rocky Mountain Arsenal study this problem in detail and include the following items:

1. Conduct pumping tests on sampling wells located in the thinner and less permeable areas of the contaminated zone for the purpose of determining rates of ground-water movement in these areas.

2. Obtain several continuous cores of the interval between the abandoned pond bottoms and the base of the shallow aquifer for the purpose of determining the existence of possible sludge deposits.

G. In view of the possibility that leakage could occur at any time from the Arsenal's lined Pond F, recording amounts of waste input and removal should be continued.

It is recommended that the Rocky Mountain Arsenal undertake the following additional measures:

1. Flush the aquifer in the vicinity of the pond with fresh water in order to permit detection of significant changes in chloride concentrations from pond sampling wells.
2. Utilize additional sampling wells located on the perimeter of the pond.
3. Conduct periodic well performance tests on the waste disposal well in order to determine trends of possible plugging.

INTRODUCTION

The investigation of ground-water conditions in the South Platte River Valley between Denver and Brighton was undertaken as a part of the water pollution study of the Denver Metropolitan Area currently being conducted by the South Platte River Basin Project.

Ground-water is used extensively in the area for public, domestic, industrial and irrigation supplies. The principal source of large ground-water supplies is the shallow valley-fill deposits which are very susceptible to contamination. The rapidly expanding urban and industrial growth of the area has resulted in continued development of water supplies from ground-water sources.

The purpose of the ground-water study was to determine sources and extent of pollution in the water-bearing formations in the area. In assessing these conditions the geology and water-bearing characteristics of the aquifers were considered.

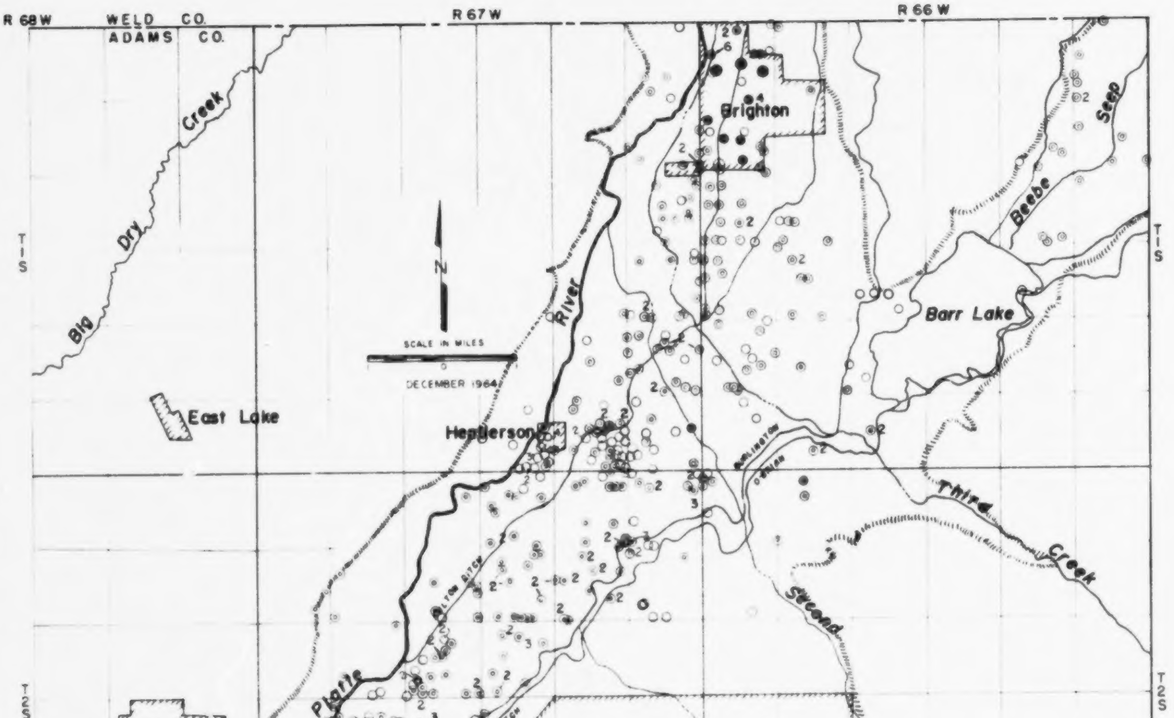
The study is based on published and unpublished information obtained from many Federal, State and local agencies, and field investigations of the area. A large number of chemical analyses of water from wells were made available by the Colorado State Department of Public Health, Tri-County Health Department, and Rocky Mountain Arsenal. The Geological Survey furnished the results of their inventory of ground-water pumpage in the area in 1963. The Ground Water Section of the Office of the State Engineer of Colorado made available their records on water wells. Officials of public water systems cooperated in furnishing information about their water systems, and permitted collection of water samples and measurements.

Locations of wells and some sampling points in the report area are described by using a numbering system based on the United States Bureau of Land Management's system of land subdivision. The numbering system is explained in Appendix A.

AREA OF INVESTIGATION

The area considered in this investigation is the valley of the South Platte River lying between Denver and Brighton, Colorado. As shown in Figure 1, the valley covers about 110 square miles in southwest Adams County.

(Figure 1 is as follows:)


R 68 W
WELD CO.
ADAMS CO.
R 67 W
R 66 W
T 1 S
T 2 S
T 3 S
Big Dry Creek
East Lake
Thornton
Brighton
Henderson
Barr Lake
Beebe Seep
Third Creek
Second Creek
First Creek
Platte River
Clear Creek
Sand Creek
Irondale
Adams City
Derby
Commerce City
ROCKY MOUNTAIN ARSENAL
UPPER DERBY LAKE
LOWER DERBY LAKE
LADORA LAKE
DENVER
Aurora
SCALE IN MILES
DECEMBER 1964
LEGEND
Irrigation well
Public supply well
Industrial well
Domestic well
Boundary of valley-fill aquifer

SOUTH PLATTE RIVER BASIN PROJECT

USE OF WATER WELLS
SCREENED IN THE
VALLEY-FILL AQUIFER

DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLO

Figure 1

The population of the principal towns in the area in 1960 (1) was: Brighton, 7055; Commerce City, 8970; Derby, 10,124; and Thornton, 11,353. Approximately 15,500 acres of farm land are presently irrigated in the main valley. The principal crops are alfalfa, corn, sugar beets, truck garden vegetables, and small grains. The principal industries in the area include oil refineries, feedlots, meat packing plants, a beet sugar processing mill and a cannery.

The South Platte River flows northeastward along the western side of the main valley. The valley is bordered on the west by a steep face of consolidated rocks and on the east by rolling uplands of consolidated rocks. The main valley consists of gently rolling hills sloping toward the broad terraces that border the flood plain of the river. Elevation of the flood plain ranges from about 5,150 feet above sea level at the south end of the area near Denver to about 4,950 feet at the north end near Brighton.

Sand Creek and First, Second and Third Creeks drain the east side of the valley. The flows in these streams are intermittent, except along the lower reaches of Sand Creek and First Creek, where these streams receive sewage treatment plant effluents, and/or treated and untreated industrial wastes. Burlington, O'Brian and Fulton ditches convey large quantities of water from the South Platte River for use on irrigated farms in and outside of the area, and for irrigation storage in Barr Lake. The west side of the valley is drained by Clear Creek, which is a perennial tributary of the South Platte River. Gardener's, Brantner and Brighton ditches divert water from the South Platte River for irrigation use on the west side of the valley.

GEOLOGY AND OCCURRENCE OF GROUND WATER

The main valley lies near the deepest portion of the Denver-Julesburg Basin; a large asymmetrical structural basin extending from central Pueblo County through northeastern Colorado into southeastern Wyoming and western Nebraska.

The upper 1,400 feet of bedrock materials of late Cretaceous and Tertiary age contain fresh water. These formations are made up of largely clay, shale and siltstone and contain many layers of poorly consolidated sandstone, gravel, and conglomerate. Ground-water in the bedrock formations generally occurs under artesian conditions. Water wells completed in the bedrock formations yield small to moderate quantities of water for domestic, stock, industrial and public supply use. Waters from the bedrock aquifers are usually of good quality except in some localities where they contain relatively high concentrations of sulfate and chloride. Wells tapping the bedrock aquifers have yields ranging from 5 to 200 gallons per minute (gpm), although most large capacity deep wells yield about 50 gpm. The low transmissivity of the water-bearing materials in the bedrock formation in this area precludes the development of large ground-water supplies from this source. Records of the State Engineer of Colorado show 139 deep water wells have been drilled in the valley through March 1964. Depths of these wells range from about 100 to 1,525 feet below the land surface.

The valley fill deposits, chiefly Quaternary in age, consist of sand, gravel, some cobbles, and thin beds of silt and clay. The valley-fill deposits blanket most of the valley. The boundary of the valley-fill deposits is shown on Figure 1. The greatest thicknesses of sand and gravel were deposited in the main channels that were cut into the bedrock by the ancestral South Platte River and its tributaries. A map prepared by the Geological Survey (2) shows the thickness of the saturated valley-fill deposits. Thicknesses of up to 60 feet of saturated valley-fill deposits occur in an ancient channel that underlies the flood plain of the present course of the South Platte River. Two buried channels, that extend northwestward across Rocky Mountain Arsenal, have saturated thicknesses of up to about 80 feet. The ancestral South Platte River originally flowed through the valley now occupied Beebe Draw. This ancient channel traverses the area in a general northeast direction roughly conforming to the present course of O'Brian Ditch. Thicknesses of the saturated fill in this ancient channel ranges up to about 100 feet beneath Barr Lake. The valley-fill deposits underlying Barr Lake are largely separated from those of the main valley by a narrow ridge of bedrock that extends northward from the southwest shore of the lake. Depths to the water table in the valley range from less than a foot beneath the flood plain to about 65 feet beneath the land surface in the southeastern part of the area.

The valley-fill deposits are the principal source of the largest supplies of ground-water in the area. Geologic conditions and water-bearing characteristics of these deposits are very favorable for developing large low-cost water supplies from wells located throughout much of the area. The Geological Survey (2) estimated about 300,000 acre-feet of recoverable ground-water in storage in 1957. Pumping tests conducted by the Geological Survey in the area reveal the coefficient of transmissibility of the aquifer ranges from 50,000 to 500,000 gallons per day per foot. The coefficient of permeability averages about 5,500 gpd per square foot. Yields of large capacity wells are reported to range up to 2,000 gpm and yields of 500 gpm are common.

WITHDRAWALS FROM THE VALLEY-FILL AQUIFER

Over 1,076 shallow wells withdraw water from the valley-fill aquifer in the area. Figure 1 shows the location and use of most of the large capacity wells in the area and is based largely on a recent inventory by the Geological Survey (3) supplemented by records of the Colorado State Department of Public Health, Tri-County Health Department and field investigations by the South Platte River Basin Project. A public supply is defined in this report as a water system that supplies water to a relatively large population. Sizes of public water systems in the area range from 121 to 7,600 service connections. A domestic supply is defined as a privately owned well system which serves residences, trailer courts, motels and similar establishments. The following tabulation is based largely on the number of shallow water wells less than 100 feet in depth recorded by the State Engineer of Colorado through March 1964.

Principal Use of Well	Total Wells
Irrigation	397
Public Supply	38
Industrial and Commercial	85
Domestic	546
Stock	10
TOTAL	1,076

Large capacity irrigation wells having yields in excess of 200 gpm are located principally in the lowland areas west of Burlington and O'Brian ditches. Of the six public water systems, well fields operated by the Northwest Water Corporation, the North Washington Water and Sanitation District and the City of Thornton are located on the flood plain of the South Platte River in the southern part of the area; those of the South Adams Water and Sanitation District and the Town & Country Mutual Water Company are lcoated in and near Commerce City; and the wells serving the City of Brighton are located within its corporate limits in the extreme northern part of the area. Most of the large capacity industrial wells are located in Brighton, and in the Commerce City industrial district. There is a heavy concentration of shallow domestic wells in the Adams City-Derby-Irondale locatility. Available records show 412 domestic wells occur in this locality. There are over 104 domestic wells in the locality bounded by Brighton, Barr Lake and Henderson. Because of the relative ease of drilling shallow wells in the main valley, the actual number of wells used for domestic and lawn irrigation purposes may be several times that reflected by available records.

The Geological Survey (2) determined total withdrawals from large capacity wells in the area averaged about 40,000 acre-feet per year during 1956 and 1957. Total withdrawals in 1963 were determined at about 32,000 acre-feet. A large part of the reduction in total pumpage is attributed to decreases in irrigated acreage in the vicinity of Adams City, Derby and Irondale, resulting from increases in residential and industrial development. The Geological Survey estimated withdrawals from 325 irrigation wells were 22,210 acre-feet in 1963 or about 70 percent of the total amount of ground-water withdrawn in the area; approximately 6,140 acre-feet of ground-water was pumped from public supply wells and 3,580 acre-feet was withdrawn from industrial wells.

M. A. Bauer

The valley-fill aquifer is the principal source of water for most public water systems in the area. The average daily deliveries of water in 1964 and the amounts contributed by pumping from the valley-fill aquifer reported by public water systems in the area are shown in the following tabulation.

	Total Water Delivered	Pumpage from Valley Fill Aquifer		
	(MGD)	(No. Wells)	(MGD)	(Percent)
City of Brighton	2.16	11	2.16	100
North Washington W&S District	0.98	4	0.74	76
Northwest Water Corporation	0.29	1	0.22	75
South Adams W&S District	2.11	8	1.56	74
City of Thornton	4.94	12	2.29	46
Town & Country Mutual Water Co.	0.09a/	2	0.09a/	100
TOTAL	10.57	38	7.06	67

a/ Estimated.

M. A. Bauer

Withdrawals from shallow wells of public supply systems have increased from an average of 7.06 million gallons per day (8,510 acre-feet per year) in 1964.

RECHARGE AND DISCHARGE

Sources of recharge to the valley-fill deposits in the area include precipitation, ground-water inflow, and seepage from irrigation ditches, irrigated farms, and influent tributary streams. Recharge water enters the valley-fill deposits and moves slowly down the valley toward points of withdrawals from wells and toward the natural discharge areas in and near the South Platte River. A water-table map prepared by Geological Survey (2) shows the hydraulic gradient varies from 11 to 30 feet per mile.

An analysis was made of amounts of recharge to and discharge from the valley-fill deposits in that portion of the main valley lying between the mouth of Clear Creek and the northern boundary of the area for the period of 1952-1961 inclusively. A summary of this analysis is shown in Table I.

(Table I is as follows:)

TABLE I

SUMMARY OF RECHARGE TO AND DISCHARGE FROM THE VALLEY-FILL DEPOSITS 1952-1961

	Acre feet per year
Recharge to the valley-fill deposits:	
Seepage from irrigation ditches	79,000
Seepage from water applied on irrigated farms	15,200
Precipitation	5,400
Ground-water inflow	9,600
Total	109,200
Discharge from the valley-fill deposits:	
Water well pumpage	32,000
Return flow to South Platte River	39,000
Evapotranspiration	34,200
Ground-water outflow	4,000
Total	109,200

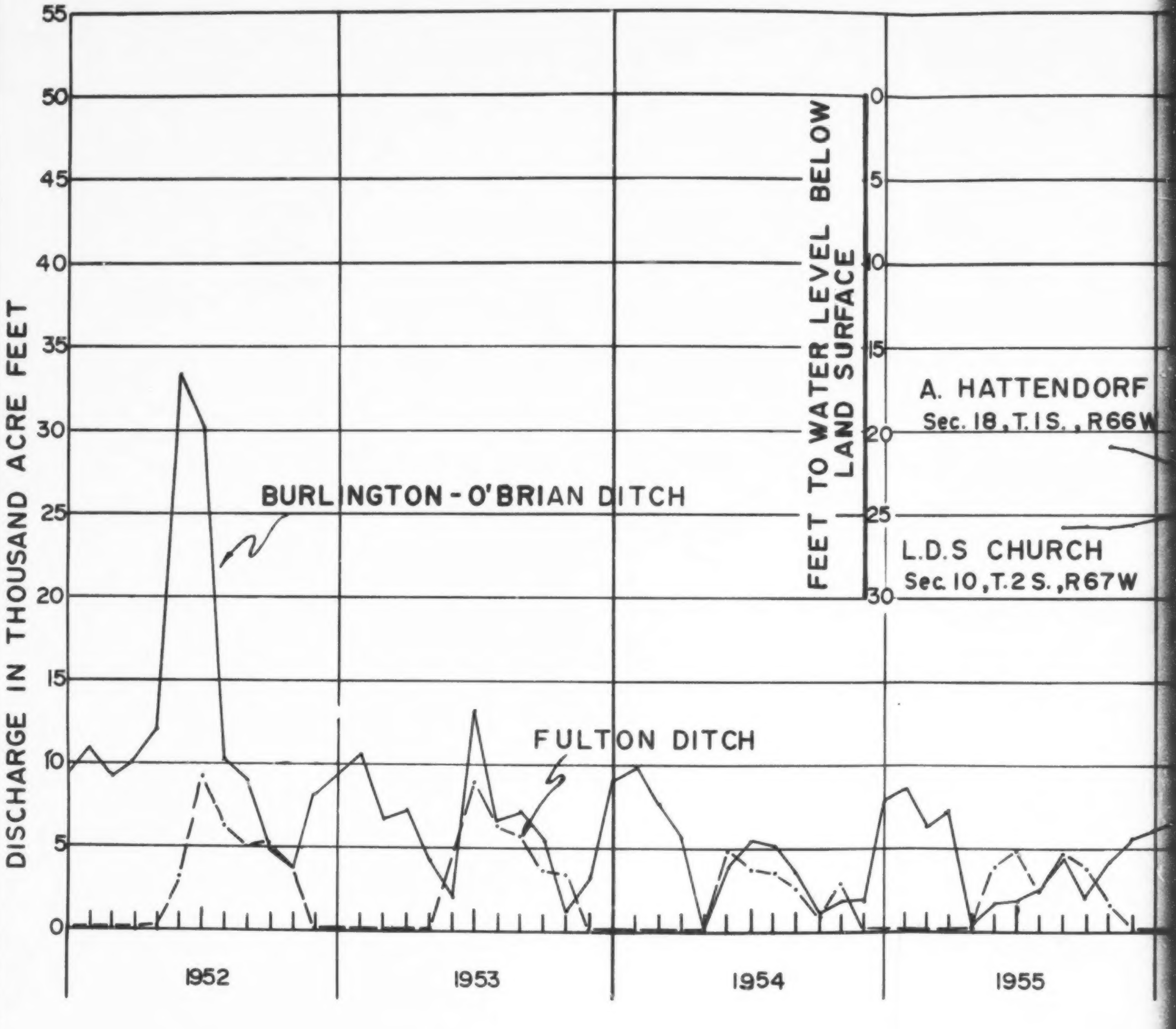
Some of the quantities of water used in this analysis are approximate. The analysis did not include recharge from runoff in intermittent streams along the margins of the main valley as this runoff is believed to be relatively small. Also, the determination of induced recharge of river flow by heavy seasonal pumping of wells located adjacent to the river is beyond the scope of this investigation. However, it is believe this amount makes up only a small part of the total recharge to the aquifer. The analysis indicates the order of magnitude of principal amounts of recharge to and discharge from the valley-fill deposits.

The chief source of recharge to the aquifer is seepage from the main irrigation ditches and seepage of waters applied on the irrigated farms. During the period of 1952-1961 inclusively, an annual average of 146,750 acre-feet was diverted to irrigation ditches in the area (4). Approximately 92,100 acre-feet of the total annual diversions to the main irrigation ditches are consumed in the area, leaving about 54,700 acre-feet available for use outside of the study area. Seepage from irrigation ditches in the area of analysis was estimated to be 79,000 acre-feet per year or 54 percent of the ditch flow. Seepage from water stored in Barr Lake was not included in the analysis, since nearly all of the seepage from the lake moves toward Beebe Seep. Approximately 250,000 acre-feet of water from wells and 13,100 acre-feet of ditch water was applied annually on the irrigated farm lands. Seepage from the irrigated farms was estimated to average 15,200 acre-feet per year, or about 40 percent of total water applied on the farms. Recharge from rainfall and snow melt in the area was estimated to average 5,400 acre-feet per year, or about 10 percent of the average annual precipitation of 13.5 inches that fell on the outcrop of the valley-fill deposits. Recharge from susurface inflow of the water-bearing valley-fill deposits located immediately upvalley was determined by the Geological Survey (2) at 9,600 acre-feet per year in 1957.

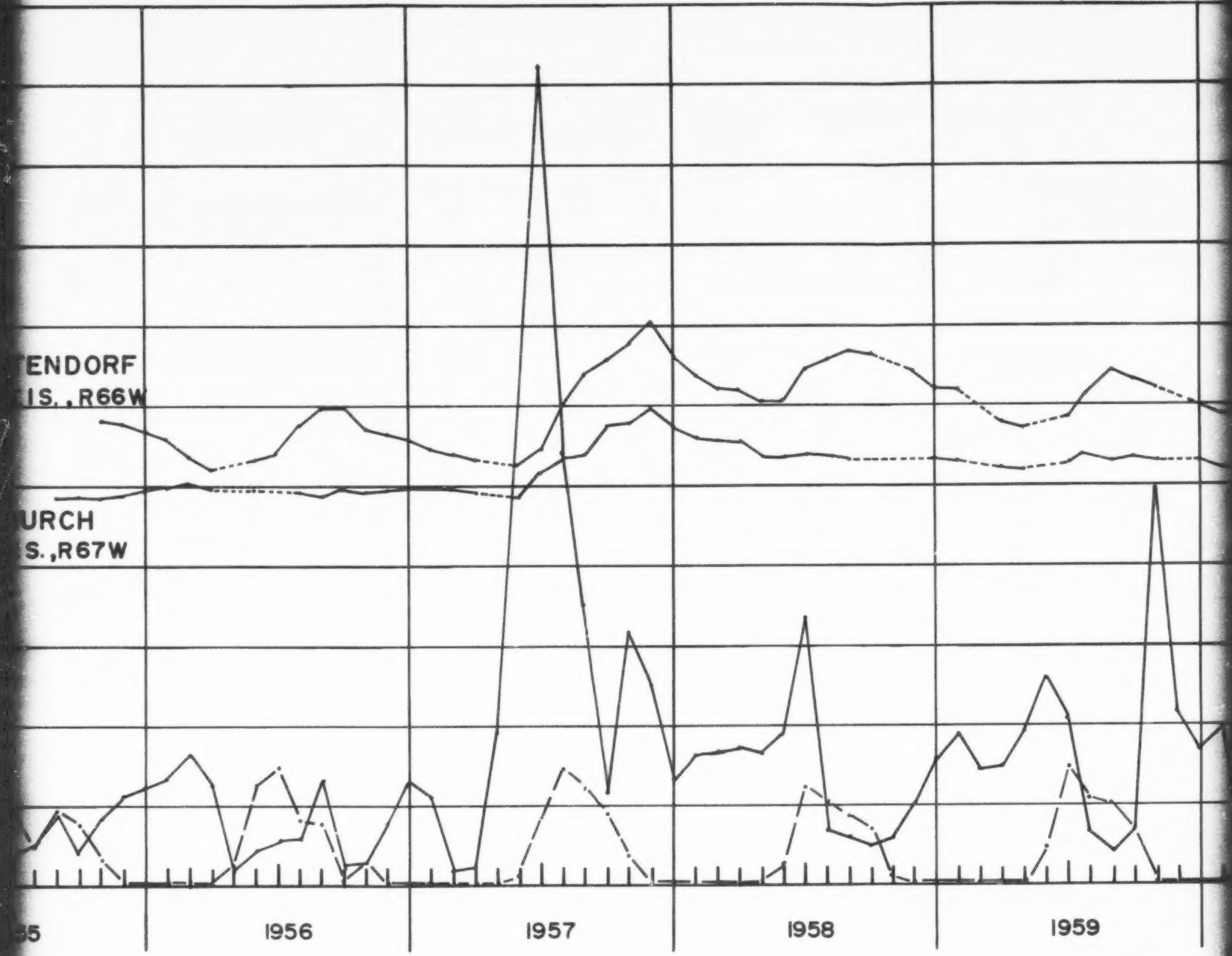
Accretions to the flow in the South Platte River occur from discharges of water from the valley-fill aquifer. River gain studies (5) indicate an average annual gain in river flow of about 34,800 acre-feet between Henderson and Fort Lupton, a distance of 13.3 miles, during the period of 1952-1961, inclusively, or a gain of about 2,600 acre-feet per year per mile. Based on the river gain shown above, discharges from ground-water return flow in the area of analysis were estimated to average about 39,000 acre-feet per year. Total annual withdrawals from large capacity wells were estimated to average about 32,000 acre-feet per year, of which 25,000 acre-feet was pumped from irrigation wells and 7,000 acre-feet was pumped from industrial and public supply wells. The amount of ground-water leaving the study area by underflow through the valley-fill deposits was estimated to be about 4,000 acre-feet per year. Discharge from the valley-fill deposits by evapotranspiration was estimated to be 34,200 acre-feet per year. A consumptive-use rate of 2 acre-feet per acre per year is considered to be applicable by the Geological Survey (2) in portions of the South Platte River Valley where the water table is less than 20 feet below the land surface.

The analysis indicates a major portion of the recharge water is derived from seepage of river water diverted to irrigation ditches. The effect of seepage from ditches and farm lands is shown in Figure 2.

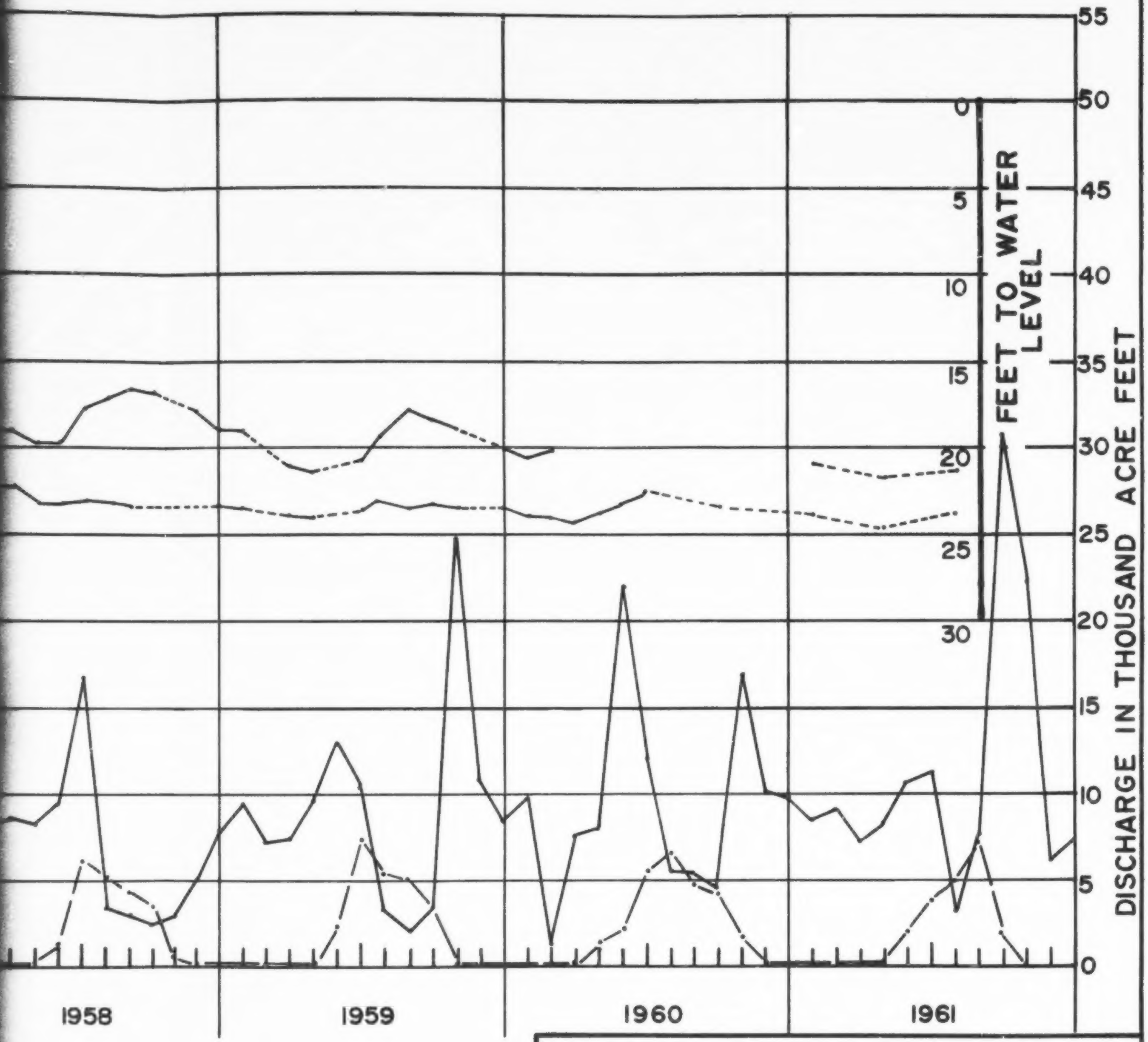
(Figure 2 is as follows:)


DISCHARGE IN THOUSAND ACRE FEET
55
50
45
40
35
30
25
20
15
10
5
0
FEET TO WATER LEVEL BELOW LAND SURFACE
0
5
10
15
20
25
30
A. HATTENDORF
Sec. 18, T.1S., R66W
L.D.S CHURCH
Sec. 10, T.2S., R67W
BURLINGTON - O'BRIAN DITCH
FULTON DITCH
1952
1953
1954
1955

A



B



SOUTH PLATTE RIVER BASIN PROJECT

WATER LEVELS IN WELLS & DIVERSIONS TO MAIN IRRIGATION DITCHES

C

DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE

REGION VIII DENVER, COLORADO

FIGURE 2

Water levels in most wells rise rapidly throughout the irrigation season and decline during the winter months. In some loaclities where wells are closely spaced, temporary declines in water levels occur during heavy pumping periods. Records of water levels in wells (2), (3), (6), (7), located throughout most of the area do not show long-term net declines, indicating over a period of years discharges from the aquifer are balanced by recharge.

CHEMICAL QUALITY OF WATER IN THE VALLEY-FILL AQUIFER

Recent chemical analyses of water from selected water wells in the area are presented in Appendix B. The chemical composition of water in the valley-fill deposits varies widely, although in most instances, total hardness of the shallow waters exceeds 200 mg/1, with concentrations of total dissolved solids and sulfates in excess of the recommended upper limits of 500 mg/1 and 250 mg/1, respectively, of the United States Public Health Service Drinking Water Standards (8).

In the southern part of the valley between Denver and Irondale, the shallow ground-water is predominantly of the calcium bicarbonate type. Total dissolved solids range from 604 to 1,510 ppm; sulfate ranges from 130 to 533 ppm and commonly exceeds 300 ppm; chloride normally ranges from 45 ppm to 180 ppm, although chlorides as low as 19 ppm and as high as 270 ppm occur in water from some wells located along the South Platte River. Alkyl benzene sulfonate (ABS) and nitrate concentrations are significant in some parts of this locality, and will be discussed in detail in a subsequent section of this report.

In the vicinity of Rocky Mountain Arsenal, the shallow ground-water is highly mineralized as a result of saline contamination from past industrial waste disposal practices. Waters in the contaminated zone are of the calcium chloride and sodium chloride types. Total dissolved solids range from 1,307 to 6,370 ppm; chloride ranges from about 220 ppm to 3,000 ppm. The contamination in the vicinity of the Arsenal will be discussed in a subsequent section of this report.

In the northern part of the valley, water in the valley-fill aquifer is predominantly of the calcium bicarbonate type. Total dissolved solids normally range from 664 to 1,110 ppm; sulfate from 191 to 489 ppm and commonly exceeds 250 ppm; chloride from 90 to 155 ppm.

Some shallow wells, which are also screened in the shallow bedrock formations yield water containing sulfate concentrations in excess of 1,000 ppm and chlorides greater than 200 ppm. Nitrate concentrations in this area commonly exceed 45 ppm [a], which is the upper limit of the United States Public Health Service Drinking Water Standards. ABS occurs throughout most of this locality.

Water quality data are not available over a sufficient period to determine long-term changes in mineralization of ground-water in most of the valley. Except in the locality affected by saline contamination from Rocky Mountain Arsenal, available data indicates the shallow aquifer in most of the valley has increased slightly or remained essentially at the same level of mineralization since intensive sampling of wells began in 1955. A limited amount of data indicates localized increases in mineralization in the northern end of the valley near the City of Brighton. In 1964, chloride and nitrate concentrations of waters from Brighton wells averaged about 128 ppm and 65 ppm respectively. Analyses of samples collected from

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[a] As NO_3

Brighton's wells No. 1, 2 and 3 indicate chloride and nitrate concentrations have increased 41 ppm and 31 ppm, respectively, since the wells were first sampled in 1943. Increases in mineralization of the Brighton locality are attributed largely to movements of ground-water from the adjacent irrigated area lying upgradient south and southeast of the city. Mineralization of the shallow ground-water underlying the heavily irrigated area has probably increased over a long period of time due to concentration of dissolved salts by continued recycling of ground-water by pumping.

Comparison of chemical analyses of ground-waters with those of waters collected by the Geological Survey (2) (9) (10) (11) (12) (13) from the South Platte River and the main irrigation ditches show similar concentrations of chloride and bicarbonate. ABS occurs in both surface and shallow ground-waters in the area. These similarities indicate a close relationship between the surface waters entering the area and water in the valley-fill aquifer. Concentrations of sulfate in the valley-fill aquifer are generally much higher than those in the surface waters.

POLLUTION OF THE VALLEY-FILL AQUIFER

Petroleum

The valley-fill aquifer is very susceptible to pollution. Water or other liquid discharged on the land surface readily enters the shallow aquifer. Contamination by gasoline and petroleum wastes has occurred in Sand Creek Valley and the main valley.

In the lower end of Sand Creek Valley, three water wells located in the northeast quarter of Section 13, T. 3 S., R. 68 W., were contaminated by a considerable quantity of gasoline in 1948 (14) (15) (16). These wells were used for irrigation and domestic purposes and one well also supplied a dairy. Approximately 2,500 gallons of gasoline were pumped from the Denver Dairy well. Subsequent test drilling showed the petroleum contamination covered an area of at least 700 by 1,300 feet by 1950 (17) (18). The valley-fill aquifer occurs between the depths of about 20 to 45 feet below the land surface in the vicinity of contaminated water wells. The total amount of gasoline lost and the exact point of leakage was not determined. Information from the files of the Colorado State Department of Public Health indicates this contamination could have been caused by leakage from facilities owned by the Oriental Refining Company, located upgradient at distances ranging from about 1,000 to 2,500 feet in a south to southeast direction from the contaminated water wells. Owners of the contaminated water wells filed a lawsuit against the company in 1951. However, the suit was dismissed. Use of the land in the locality of contamination has changed almost entirely to industrial and commercial tracts. Drinking water is now supplied by the Denver water system. Although the movement of the gasoline in the aquifer since 1950 is not defined, the valley-fill aquifer in this locality is probably contaminated at the present time and will remain contaminated for many years in the future.

In 1957, the Geological Survey (2) reported the odor of petroleum in the water from a stock well located in Commerce City in Section 7, T. 3 S., R. 67 W (3-67-7daba). In the same locality analysis of water from the Town & Country Mutual Water Company Well No. 1 (3-67-7addd) by the Public Health Service (19) in 1957 revealed contamination by hydrocarbons, plastic-like material and ABS. Recent chemical analyses of water samples obtained from Town & Country Mutual Water Company Well No. 1 by the Project revealed 2 ppm of oil; 2 ppm of oil was also detected in a water sample taken from Town & Country Well No. 2 (3-67-7 acaa).

The occurrence of hydrocarbons in the valley-fill aquifer in the locality of the Town & Country wells is attributed to discharges of petroleum-laden water into Sand Creek Valley. Recharge to the aquifer in this locality occurs largely in that portion of Sand Creek Valley lying upgradient, south to southeast, from the Town & Country well field. The storm sewer outfalls of Stapleton Airport on Sand Creek are located upvalley about 2.5 miles southeast of Town & Country well field. Available data indicate substantial amounts of petroleum-laden water have been discharged into Sand Creek from storm sewers at Stapleton Airport. Part of this flow enters the valley-fill deposits through the sandy bed of the creek and thence moves downgradient toward the South Platte River Valley. Discharges into storm sewers of the airport include detergent wastes from washing of the airplanes and solvent and oily wastes from engine overhaul and cleaning operations. Approximately 0.10 million gallons per day (mgd) of waste water are currently discharged into Sand Creek from Stapleton Airport. Records from the files of the Colorado State Department of Public Health show grab samples taken from storm sewer outfalls at the airport contained 141,000 ppm oil on October 20, 1961; 77.2 ppm and 15.6 ppm on May 3, 1963; 62.2 ppm on July 24, 1963; and 114 ppm on March 30, 1964. Nine grab samples taken from the storm sewer outfall of the airport by the Project between September 29 and October 1, 1964, contained oil concentrations that ranged from 14 to 118 ppm.

Waste discharges by refineries of Oriental Refining Company, Tenneco Oil Company and Empire Petroleum Company have contributed some petroleum to the valley-fill aquifer in the lower Sand Creek Valley and the adjoining area of the main valley in the Commerce City area. Also, disposal of oily wastes on the land surface or in shallow pits by repair garages and service stations in the Commerce City area probably have contributed some petroleum to the valley-fill aquifer.

In the past, Oriental Refining Company has discharged from 0.4 to 0.7 mgd of waste water into two earthen settling ponds, which in turn empty into Sand Creek. Records from the files of the Colorado State Department of Public Health show five grab samples of pond effluent, taken in 1963, contained oil concentrations that ranged from 1.0 to 5.2 ppm. Undoubtedly, substantial amounts of waste water have entered the aquifer through the bottom of these earthen ponds, because they are located in the sandy outcrop of the valley-fill aquifer.

Empire Petroleum Company currently discharges approximately 0.45 mgd of waste water into a large earthen settling pond which in turn flows into Sand Creek. Records of the Colorado State Department of Public Health show oil concentrations of five grab samples of pond effluent taken in 1963 contain oil concentrations that ranged from 9.9 to 17.3 ppm. Composite samples of pond effluents obtained by the Project on October 7 and 8, 1964, indicated an average oil concentration of 3.5 ppm. Substantial amounts of seepage probably enter the valley-fill aquifer from Empire's pond.

Tenneco currently discharges about 0.6 mgd of waste water into Sand Creek. Records of the Colorado State Department of Public Health show oil concentrations of three grab samples of Tenneco's effluents in 1963 ranged from 8.6 to 58 ppm. Composite samples obtained by the South Platte River Basin Project on October 7 and 9, 1964, showed oil concentrations of Tenneco's effluents averaged about 3 ppm.

Continental Oil Company currently discharges about 0.3 mgd of waste water into Burlington-O'Brian Ditch. Records of the Colorado State Department of Public Health show oil concentrations of five grab samples of Continental's effluent in 1963 ranged from 13.2 to 22.1 ppm. A large part of the effluent from Continental's outfall enters the valley-fill aquifer through the bed of Burlington-O'Brian Ditch.

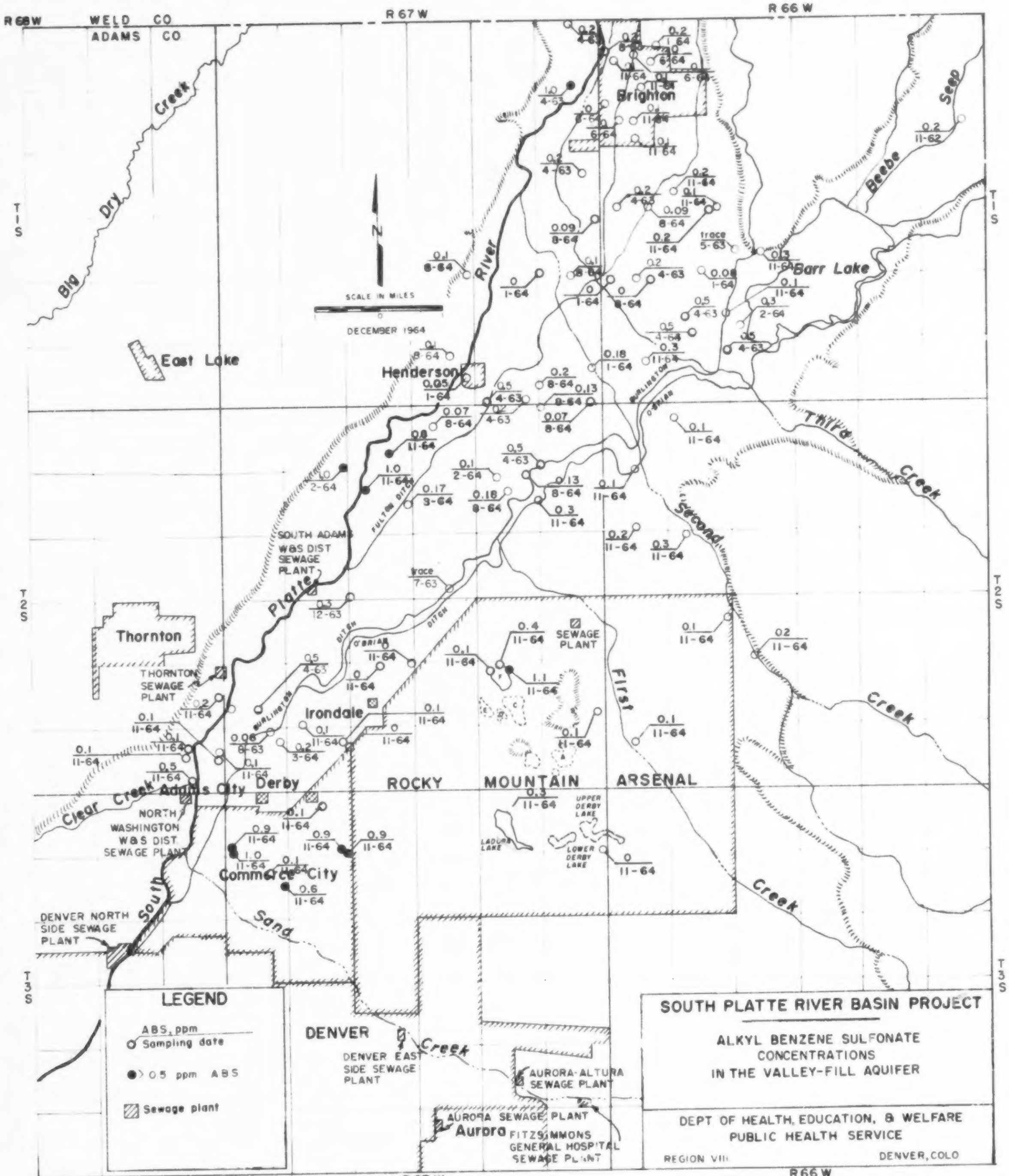
In the main valley west of Irondale, two springs of the State Fish Hatchery, located in Section 20 of T. 2 S., R. 67 W. (2-67-20cca), were contaminated by gasoline reportedly in about 1955 (2) (3). These springs discharge water from the valley-fill aquifer near the base of a terrace that borders the flood plain of the South Platte River. Approximately 2,300 feet southeast of the springs, a water well 2-67-29bcd) owned by Jake and Mary Kramer reportedly yielded appreciable amounts of gasoline in about 1954 (14). The well was about 50 feet in depth and used for domestic and irrigation purposes.

The springs were abandoned as a source of water for hatching fish and replaced by a deep well screened in the bedrock aquifer. Similarly, the contaminated shallow well owned by Jake and Mary Kramer was abandoned and replaced by a deep well as a source of potable water. Contamination of these water supplies could have been due to leakage from nearby petroleum product pipelines and storage tanks owned by Wyco Pipe Line Company. However, the pipeline company reported their investigation revealed that no leakage had occurred in the pipeline or storage tanks. The storage tanks and connecting pipeline are located about 4,000 feet southeast and 800 feet southwest of the Fish Hatchery springs, respectively. The contaminated water well lies about 2,100 feet north of the storage tanks and 1,500 feet northeast of the connecting pipeline. The water table at the springs and well lie downgradient from the storage tanks and portions of the connecting pipeline. A portion of this area remains contaminated, since one of the Fish Hatchery springs continues to issue small amounts of petroleum.

Alkyl Benzene Sulfonate

ABS has been detected in most shallow well waters in the main valley. Figure 3 shows ABS concentrations in waters from wells screened in the valley-fill aquifer.

(Figure 3 is as follows:)


R 68 W
R 67 W
R 66 W
WELD CO
ADAMS CO
T 1 S
T 2 S
T 3 S
Big Dry Creek
East Lake
Brighton
Henderson
Barr Lake
Beebe Seep
Third Creek
Second Creek
First Creek
Thornton
THORNTON SEWAGE PLANT
SOUTH ADAMS W&S DIST SEWAGE PLANT
South Platte River
Clear Creek
Adams City
Derby
Irondale
Commerce City
NORTH WASHINGTON W&S DIST SEWAGE PLANT
DENVER NORTH SIDE SEWAGE PLANT
Sand Creek
ROCKY MOUNTAIN ARSENAL
SEWAGE PLANT
UPPER DERBY LAKE
LOWER DERBY LAKE
LADORA LAKE
DENVER
DENVER EAST SIDE SEWAGE PLANT
AURORA-ALTURA SEWAGE PLANT
AURORA SEWAGE PLANT
Aurora
FITZSIMMONS GENERAL HOSPITAL SEWAGE PLANT
FULTON DITCH
O'BRIAN DITCH
BURLINGTON
N
SCALE IN MILES
DECEMBER 1964
LEGEND
ABS, ppm
○ Sampling date
● > 0.5 ppm ABS
▨ Sewage plant

SOUTH PLATTE RIVER BASIN PROJECT

ALKYL BENZENE SULFONATE CONCENTRATIONS IN THE VALLEY-FILL AQUIFER

DEPT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLO

Figure 3

Public water supplies in the area obtain all or a large part of their water from wells screened in the valley-fill aquifer. Table II shows ABS concentrations in water samples obtained from many of the shallow public supply wells in the area.

(Table II is as follows:)

TABLE II

ABS CONCENTRATIONS IN WATER FROM PUBLIC SUPPLY WELLS

	Location (T-R-Sec.)	Owner's Well No.	Well Depth(ft)	Sampling Date	ABS ppm	Analyst[a]
City of Brighton	1-66-7abb	1,2,3	40,50,40	11/9/64	0.1[b]	P
	1-66-7abac	4	33	6/3/64	0.1	C
	1-66-6dacd	6	50	6/3/64	0.0	C
	1-66-7dbcd	7	55	11/9/64	0.1	P
	1-66-6cbdd	8	35	11/9/64	0.1	P
	1-66-6dbbc	10	42	6/3/64	0.0	C
	1-66-7dccb	11	62	11/9/64	0.1	P
	1-66-7cabc	12	66	6/3/64	0.0	C
	1-66-7bcbd	13	65	6/3/64	0.0	C
North Washington W.S.D.	2-68-36bda	Gallery #1	18	11/9/64	0.1	P
	2-68-36bda	Gallery #2	25	11/9/64	0.1	P
Northwest Water Corp.	2-68-36dcbc	#1	29.5	8/5-28/63	0.55[c]	C
	2-68-36dcbc	#1	29.5	11/9/64	0.5	P
South Adams W.S.D.	2-67-29cdc	#2(S-9)	80	11/12/64	0.1	P
	2-67-32adc	#2(S-8)	100	11/12/64	0.0	P
	2-67-32adc	#3	93	11/12/64	0.1	P
	3-67-5abcd	#2(S-7)	80	11/12/64	0.1	P
	3-67-5dddd	#2(S-5)	80	11/12/64	0.9	P
	3-67-5dddd	#3(S-6)	80	11/12/64	0.9	P
	3-67-6ccdc	#2(S-2)	43	11/12/64	0.9	P
	3-67-6ccdc	#3(S-3)	45	11/12/64	1.0	P
City of Thornton	2-68-25daaa	#5	26	11/16/64	0.2	P
	2-68-36aada	#12	29	11/16/64	0.1	P
	2-68-36aadd	#15	29	11/16/64	0.1	P
Town & Country Mutual Water Co.	3-67-7addd	#1	42	7/26/57	0.65[d]	P
	3-67-7addd	#1	42	11/24/64	0.6	P
	3-67-7acaa	#2	22	11/24/64	0.1	P

[a] P - U.S. Public Health Service; C - Colorado State Department of Public Health.

[b] Composite of 3 wells.

[c] Average of 17 grab samples.

[d] Carbon filter operated July 17-26, 1957.

ABS concentrations, in excess of the upper recommended limit of 0.5 ppm of the United States Public Health Service Drinking Water Standards, occur in water from one well owned by the Town & Country Mutual Water Company located in Commerce City. An analysis of a water sample collected in November 1964 from Well No. 1 by the Project shows 0.6 ppm ABS. An analysis of water from this well by the Public Health Service (19) in 1957 revealed similar concentrations of ABS. Chemical analyses of waters from four shallow wells owned by the South Adams Water and Sanitation District reveal ABS concentrations ranging from 0.9 to 1.0 ppm in November 1964.

Northwest Water Corporation and North Washington Water and Sanitation District obtain a large portion of their water supplies from shallow wells or galleries located on the flood plain on the west side of the South Platte River in Section 36, T. 2 S., R. 68 W. During heavy pumping periods of the summer months, much of the water pumped from these wells and galleries is derived from induced infiltration of flows in the South Platte River. During August 1963, the Colorado State Department of Public Health (20) collected 17 grab samples from the Northwest Water Corporation well. Analyses of these water samples show ABS concentrations averaged 0.55 ppm during this period. A sample collected from the well in November 1964 by the Project showed an ABS concentration of 0.5 ppm. Analyses of water samples collected by the Project in November 1964 from two galleries owned by North Washington Water and Sanitation District revealed ABS concentrations of 0.1 ppm each.

The City of Thornton obtains most of its ground-water supply from two well fields located in and near the flood plain of the South Platte River (21). Well Field No. 1, consisting of 7 shallow wells and one deep well, is located on the west side of the river in Section 25, T. 2 S., R. 68 W., and Section 30, T. 2 S., R. 67 W. Much of the water pumped from the shallow wells in Well Field No. 1 is derived from induced filtration of the river flow. An analysis of a sample taken from one of these wells in November 1964 by the Project showed an ABS concentration of 0.2 ppm. Well Field No. 2, consisting of five shallow wells, is located on the east side of the river in Section 36, T. 2 S., R. 68 W. Analysis of water samples collected from two wells in this field in November 1964 by the Project revealed ABS concentrations of 0.1 ppm each.

ABS was detected in many of the City of Brighton's well waters. Analyses of water samples obtained from eleven of Brighton's wells by the Project and the Colorado State Department of Public Health during 1964 show ABS concentrations of 0.1 ppm occurred in seven wells; ABS was not detected in four.

The high concentrations of ABS in well waters in the Commerce City area are due largely to recharge water derived from industrial and sewage plant effluents discharged into Sand Creek. A substantial part of the flow enters the valley-fill aquifer through the sandy bed of the creek and continues to move downgradient toward the main valley. Sand Creek currently receives an average of 5.7 mgd (6,385 acre-feet per year) of effluents from five sewage treatment plants and an average of 1.2 mgd (1,344 acre-feet per year) from industrial outfalls. Samples obtained from the surface flow near the mouth of Sand Creek in September 1964 by the Project revealed an average ABS of 1.6 ppm.

Although discharges from sewage treatment plants probably contribute the major portion of ABS to the creek, some industrial discharges are also significant. Samples taken from a Stapleton Airport outfall on Sand Creek in September and October 1964 by the Project showed ABS concentrations ranged from 22 to 64 ppm and averaged 44 ppm. The following tabulation, based on records from the files of the Colorado State Department of Public Health, shows ABS in grab samples of effluents discharged by refineries.

Refinery	Outfall	Sampling Date	ABS ppm
Oriental Ref. Co.	Sand Creek	Nov. 1963	0.24
Empire Pet. Co.	Sand Creek	Nov. 1963	0.39
		Mar. 1964	0.30
Tenneco Oil Co.	Sand Creek	Nov. 1963	3.2
		Mar. 1964	3.5
Continental Oil Co.	Burlington Ditch	Nov. 1963	2.7
		Mar. 1964	1.75
		July 1964	0.9

Septic tanks most likely contribute significant amounts of ABS to the valley-fill aquifer. A total of over 685 domestic wells in the study area would indicate a similar number of septic tanks in use. Many shallow domestic wells in the suburban area near Adams City, Derby, and Irondale and the rural area bounded by Brighton, Barr Lake and Henderson, yield water containing ABS derived from septic tank effluents. As shown in Figure 3, the effects of septic tanks are most apparent in the rural area lying east of O'Brian Ditch, where ditch water is not applied on the irrigated farms.

The occurrence of ABS in the valley-fill aquifer underlying the Rocky Mountain Arsenal resulted from previous waste disposal practices of conveying industrial wastes in unlined canals and discharging these wastes into unlined holding ponds. Discharges from the Arsenal's sewage treatment plant contribute small amounts of ABS to the aquifer in the vicinity of First Creek. An analysis of a water sample obtained by the Project in November 1964 from First Creek showed an ABS content of 0.2 ppm.

The principal source of ABS in the valley-fill aquifer in the main valley is recharge water originating from sewage treatment plant discharges into the South Platte River, Clear Creek and Sand Creek. A large portion of these sewage-laden waters are diverted to the irrigation ditches in the area, and in turn, enter the shallow aquifer from seepage in the ditches and irrigated farms.

The Denver Northside treatment plant currently discharges an average of 70.3 mgd (78,775 acre-feet per year) of partially treated sewage into the South Platte River. Two smaller sewage treatment plants discharge an average of 4.1 mgd (4,594 acre-feet per year) to the

South Platte River between Clear Creek and Fulton Ditch. Clear Creek currently receives an average of 16 mgd (17,929 acre-feet per year) from nine sewage treatment plants. Table III shows ABS concentrations in the waters of the streams and main diversion ditches in the area.

(Table III is as follows:)

TABLE III

ABS CONCENTRATIONS IN SURFACE WATERS

	Location of Station				ABS, ppm		
Water Course	Miles below N. Denver STP	Other	Period	No. of Samples	Range	Average	Analyst[a]
So. Platte River	---	0.2 mile above N. Denver STP	2/62-11/62	10	0.4-0.9	0.7	G
	1.1	---	2/62-11/62	9	0.8-2.6	1.7	G
	3.3	---	8/63	17	0.6-1.3	0.9	C
	12.8	---	2/62-11/62	9	1.2-2.2	1.8	G
Burlington Ditch	1.0	---	3/64-11/64	6	0.3-2.4	1.3	P
	5.7	---	10/62-4/63	2	2.4-3.0	2.7	G
	12.5	---	10/62-4/63	3	1.6-4.0	2.7	G
	17.8	---	10/62-4/63	3	1.3-2.0	1.7	G
O'Brian Ditch	11.5	---	11/62	1	1.6	1.6	G
	17.8	---	3/64-6/64	5	0.8-2.4	2.0	P
Fulton Ditch	8.8	---	7/64	10	1.0-2.6	1.9	P
	15.6	---	10/62-4/63	3	0.3-3.0	1.7	G
Sand Creek	---	Mouth	9/64	3	0.5-2.9	1.6	P
Clear Creek	---	Mouth	8/63	17	0.7-1.2	0.8	C
	---	Mouth	9/64	2	0.1-1.1	0.6	P

[a] C - Colorado State Department of Public Health
G - U.S. Geological Survey
P - U.S. Public Health Service

A study conducted by the United States Geological Survey (22) during 1961-1963 indicates the Denver Northside sewage treatment plant is a major source of ABS in the South Platte River. During 1962, ABS concentrations increased an average of 1.0 ppm immediately downstream from Denver's sewage treatment plant. Significant amounts of ABS occur throughout the South Platte River and its tributaries, Sand Creek and Clear Creek. Similar amounts of ABS occur in river water diverted to Burlington, O'Brian and Fulton ditches.

ABS concentrations in the valley-fill aquifer are generally lower than ABS concentrations in the streams and irrigation ditches. Results of laboratory infiltration studies conducted by the United States Geological Survey (22) indicate ABS is reduced by seepage through the unsaturated zone above the water table. Some ABS removal occurs during infiltration through the saturated zone. ABS concentrations in water from wells located near the river, that probably induce infiltration from the river during heavy pumping periods, are consistently lower than ABS concentrations in the river water, but nevertheless significant.

Bacteria

Bacteria are significantly reduced by infiltration through the aquifer, although complete removal of bacteria over relatively short distances may not be accomplished. A pond located near the confluence of Clear Creek and the South Platte River is excavated below the water table. A large capacity public supply well owned by Northwest Water Corporation is located on the west edge of the pond. The pond is about 150 feet from the river and about 650 feet downstream from the outfall of North Washington Water and Sanitation District sewage treatment plant on Clear Creek. During sustained periods of pumping from the well, most of the water in the pond is induced infiltration from the river.

Grab samples of South Platte River water taken in August 1964 by the Project at a sampling point located about two miles upstream from the pond showed a median total coliform density of 7,900,000 per 100 ml and a median fecal coliform density of 5,950,000 per 100 ml. Samples taken near the mouth of Clear Creek by the Project in September 1964 showed a median total coliform density of 254,000 per 100 ml, and a median fecal coliform density of 101,500 per 100 ml. Samples of pond water collected by the Project on a weekly basis in September, October and November 1964 showed total coliform densities ranged from 49 to 1,300 per 100 ml and fecal coliform densities ranged from less than 1.8 to 4.5 per 100 ml.

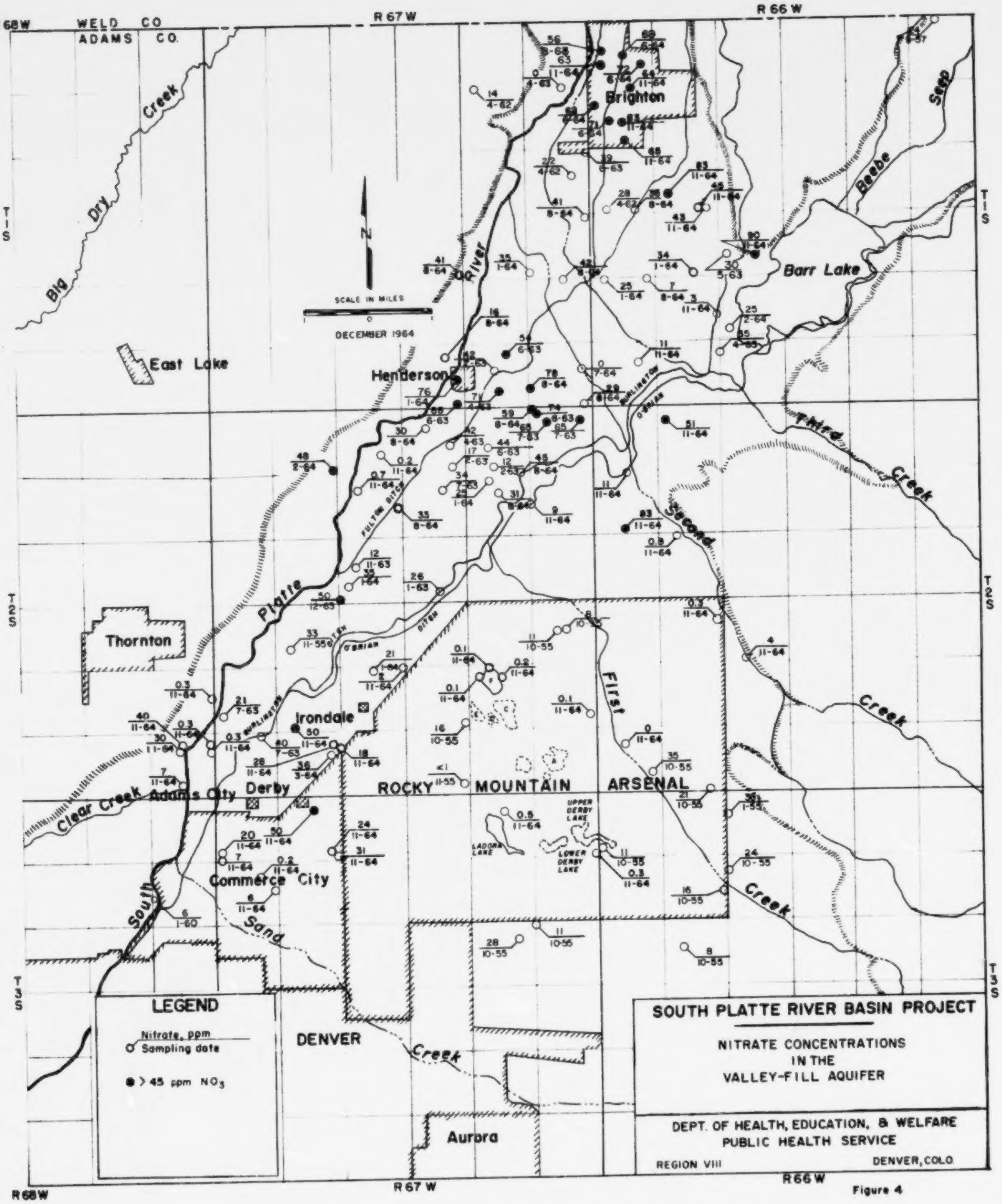
Similar removal of bacteria occurs in water produced from two public supply galleries owned by North Washington Water & Sanitation District, located about 2,500 feet north of the confluence of Clear Creek and the South Platte River. The galleries are located about 300 feet west of the river. Samples of water collected from the two galleries on a weekly basis by the Project in September and October 1964 showed total coliform densities ranged from less than 1.8 to 23 per 100 ml; fecal coliform densities ranged from less than 1.8 to 2 per 100 ml.

Nitrate

The United States Public Health Service Drinking Water Standards (8) state the nitrate content of water should not exceed an upper limit of 45 ppm. Domestic water containing excessive amounts of nitrate is potentially dangerous when used for infant feeding.

As shown in Figure 4, the highest nitrate concentrations in the valley-fill aquifer generally occur in and near the irrigated lowlands lying between Brighton and Commerce City.

(Figure 4 is as follows:)


R 68 W
WELD CO
ADAMS CO
R 67 W
R 66 W
T 1 S
T 2 S
T 3 S
Big Dry Creek
East Lake
N
SCALE IN MILES
DECEMBER 1964
Brighton
Henderson
Barr Lake
Beebe Seep
Third Creek
Second Creek
First Creek
Platte River
South Platte
Fulton Ditch
O'Brian Ditch
Burlington
Thornton
Irondale
Adams City
Derby
Clear Creek
Commerce City
Sand Creek
ROCKY MOUNTAIN ARSENAL
Upper Derby Lake
Lower Derby Lake
Ladora Lake
DENVER
Aurora
LEGEND
Nitrate, ppm
Sampling date
● > 45 ppm NO_3

SOUTH PLATTE RIVER BASIN PROJECT

NITRATE CONCENTRATIONS
IN THE
VALLEY-FILL AQUIFER

DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLO.

Figure 4

M. A. Bauer

Nitrate concentrations in this area commonly exceed 35 ppm. The lowest concentrations generally occur near the South Platte River and in the non-irrigated upland areas.

Available analyses show 40 wells in the study area yield water having nitrate concentrations in excess of 45 ppm, of which 12 are public supply wells, at least 7 wells are used for domestic purposes, and one well is used to supply process water to a cannery. Detailed information on these wells is shown in Table IV.

(Table IV is as follows:)

TABLE IV

NITRATE CONCENTRATIONS IN WATER FROM SELECTED WATER WELLS

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Nitrate ppm	Analyst[b]
1-66-6ac	C. Baker	N.R.	30	4/4/63	54	C
1-66-6ac	M. Poff	N.R.	30	4/4/63	54	C
1-66-6bb	L. Knodel	N.R.	30	4/3/63	63	C
1-66-6cba	Kuner-Empson	C,P	30	8/12/63	56	C
1-66-6cbdd	Brighton #8	P.S.	35	11/9/64	62.9	P
1-66-6dacd	Brighton #6	P.S.	50	6/3/64	72	C
1-66-6dbbc	Brighton #10	P.S.	42	9/21/60	59	G
1-66-6dbbc	Brighton #10	P.S.	42	6/3/64	69	C
1-66-7abac	Brighton #4	P.S.	33	6/3/64	55	C
1-66-7abb	Brighton #1, 2,3	P.S.	40,50 40	11/9/64	62.9	P
1-66-7babd	Brighton #13	P.S.	65	6/3/64	62	C
1-66-7cabc	Brighton #12	P.S.	66	6/3/64	71	C
1-66-7dbcb	Brighton #7	P.S.	55	11/9/64	62.9	P
1-66-7dccb	Brighton #11	P.S.	62	11/9/64	64.7	P
1-66-17cbdc	L. Darras	I	28	11/23/64	82.9	P
1-66-21cad	Barr Lake Inn	D	50	11/9/64	89.5	P
1-66-21dc	L. Herbeck	N.R.	55	5/13/63	53	C
1-67-34daab	R. Miller	D	18	1/6/64	76	C
1-67-34da	M. Burbach	D	26	6/17/63	83	C
1-67-34da	M. Burbach	I	13	6/17/63	89	C
1-67-34da	R. Scott	N.R.	15	6/17/63	88	C
1-67-34da	C. Nichols	N.R.	15	6/17/63	90	C
1-67-34da	A. Ross	N.R.	15	6/17/63	83	C
1-67-34ddcd	A. Adams	I	10	6/10/63	88	C
1-67-35abd	W. Johnson	N.R.	--	6/24/63	54	C
1-67-35dcbb	J. Carlson	N.R.	32	4/18/63	71	C

---

[a] C - Cooling, D - Domestic, I - Irrigation, L.I. - Lawn Irrigation, N.R. - Not Reported, P - Processing, P.S. - Public Supply, S - Stock.

[b] C - Colorado State Department of Public Health, G - U.S. Geological Survey, P - U.S. Public Health Service, U - Colorado State University.

TABLE IV (Continued)

Nitrate Concentrations in Water from Selected Water Wells

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Nitrate ppm	Analyst[b]
1-67-36cbcc	C. Shaw	D	38	8/11/64	78	C
1-67-36	D. Gilmer	N.R.	40	4/17/63	61	C
2-66-5caa	E. Kallsen	S	42	11/23/64	51	P
2-66-7dcdc	S. Wawok	D	55	11/23/64	82.9	P
2-67-1adbb	G. Squires	I	34	7/16/63	65	C
2-67-1bbbb	J. Salthouse	D	46	8/11/64	59	C
2-67-1bb	R. Weaver	N.R.	44	6/24/63	74	C
2-67-1bdbb	G. Squires	I	40	7/16/63	65	C
2-67-2db	J. Erger	N.R.	45	7/30/63	50	C
2-67-5dddd	T. Abbott	N.R.	--	2/10/64	48	C
2-67-16cccc	D. Latorra	N.R.	50	12/17/63	50	C
2-67-29cdc	S. Adams WSD Well #2(S-9)	P.S.	80	11/12/64	50.1	P
2-67-32ab	E. Bungard	N.R.	45	8/6/63	58	C
3-67-5abc	S. Adams WSD Well #2(S-7)	P.S.	80	11/12/64	50.1	P
3-67-5cd	D. Pfeif	N.R.	65	8/6/63	58	C
3-67-6ab	R.E. Murfine	D	32	11/5/43	48	U

---

[a] C - Cooling, D - Domestic, I - Irrigation, L.I. - Lawn Irrigation, N.R. - Not Reported, P - Processing, P.S. - Public Supply, S - Stock.

[b] C - Colorado State Department of Public Health, G - U.S. Geological Survey, P - U.S. Public Health Service, U - Colorado State University.

Water from 11 wells currently used by Brighton have nitrate concentrations ranging from 55 to 72 ppm. Available analyses indicate high nitrates have existed in Brighton's water supply for at least 21 years. A sample collected from Well No. 10 in 1960 revealed a nitrate concentration of 59 ppm (3). Four composite water samples collected from Wells No. 1, 2 and 3 during the period of 1943-1945 contained nitrates ranging between 20 and 32 ppm (23). Water from Wells No. 1, 2 and 3 had a nitrate concentration of 63 ppm in November 1964; these data indicate an increase of 31 to 43 ppm since the 1943-1945 period. One case of infant methemoglobinemia in 1962 was attributed by the Tri-County Health Department to high nitrates in Brighton's ground-water supply (24).

Nitrate concentrations in the valley-fill aquifer are excessive throughout the Brighton area. A cannery and beet sugar processing mill in the Brighton area obtain process water from shallow wells screened in the valley-fill aquifer. A water sample taken by the Tri-County Health Department from one of the cannery's wells in August 1963 shows a nitrate concentration of 56 ppm.

In the southern part of the valley, analyses of water from a well (3-67-6ab) near Adams City revealed nitrates varied from 24 to 48 ppm during the period of

1943-1945 (23). Analyses of water from wells in this locality show essentially the same level of nitrate concentrations occurred in 1964.

Two shallow wells owned by the South Adams Water and Sanitation District, located in the Commerce City area, yield high nitrate waters. Water samples collected by the Project from Wells No. S-7 (3-67-5abcd) and S-9 (2-67-29cdc) in November 1964, revealed nitrate concentrations of about 50 ppm.

A report by Colorado State University (23) indicates high nitrate concentrations occurred in South Platte River water as early as 1945. Samples taken at a point located immediately below the North Denver sewage treatment plant outfall show the following: nitrates were not detected in samples collected in November 1943, April 1944 and November 1944; 32 ppm nitrate was detected in a sample collected in March 1945.

Records of chemical analyses of surface water by the Geological Survey (2) (9) (10) (11) (12) (13) show the following: Analyses of South Platte River water at a sampling point located 0.8 mile below the Denver Northside treatment plant outfall show nitrate concentrations averaged 36 ppm between September 1955 and May 1956. Nitrate concentrations of Burlington ditch water, obtained at a sampling point located 0.7 mile below the Denver sewer outfall averaged 31.5 ppm between September 1955 and April 1956, and averaged 1.1 ppm between October 1962 and September 1963. Nitrate concentrations of South Platte River water at the Henderson station averaged 9.8 ppm between July 1955 and September 1957, and averaged 0.8 ppm between October 1962 and September 1963. The amounts of nitrate contributed to the valley-fill aquifer from sewage-laden waters diverted for irrigation use in the area are believed to be very significant but cannot be fully assessed from available records. Available analyses of surface waters do not include determinations of ammonium and nitrite concentrations, which are probably converted to the nitrate form of nitrogen after entering the shallow valley-fill deposits.

The use of fertilizers on irrigated farms in the area probably contributes the major portion of nitrates to the valley-fill aquifer. Large quantities of commercial nitrogen fertilizers are applied annually on about 15,500 acres of land in the valley. Information provided to the Project by the Soil Conservation Service office at Brighton indicated that 50 to 100 pounds per acre of commercial fertilizers are applied annually on irrigated farms, with nitrogen contents of 10 to 20 percent by weight. In addition, large quantities of liquid anhydrous ammonia are added directly to the water applied on many of the irrigated farms in the area. Approximately 40 percent of the water applied on the irrigated lands enters the shallow aquifer through permeable soils of the valley-fill outcrop.

Six feedlots are located between Denver and Henderson. Surveys by the Project indicate an estimated 26,500 to 28,500 cattle and about 11,000 sheep are held within these feedlots. Large quantities of manure, accumulated on the sandy soils of the valley-fill deposits, are subject to leaching from precipitation and waste water. Thus, recharge water derived from leaching and drainage from these accumulations readily enters the shallow valley-fill aquifer. Feedlot operations probably contribute substantial amounts of nitrate to the aquifer in local areas, although available data indicate these operations are not the principal source of nitrate pollution in the main valley.

Previous waste disposal practices by the Rocky Mountain Arsenal are not a major source of nitrates in the valley; however, available data indicate the Arsenal has contributed some nitrates to the shallow aquifer in the immediate vicinity. Analyses of contaminated saline water from wells located on the Arsenal property show nitrate concentrations range from 0.1 to 16 ppm. The 1954-56 Geological Survey study (13) of saline contamination revealed nitrate concentrations in two unlined holding ponds and an unlined ditch ranged from 1.8 to 22 ppm; water samples collected from First Creek, below the outfall of Arsenal's sewage treatment plant, had nitrate concentrations ranging from 3 to 49 ppm. A sample collected by the Project from First Creek in November 1964 shows a nitrate concentration of 12.8 ppm.

Contamination in the Vicinity of Rocky Mountain Arsenal

Previous waste disposal practices by the Rocky Mountain Arsenal have resulted in contamination of the valley-fill aquifer in the area between Irondale and Henderson. Numerous investigations of the effect and extent of this contamination have been conducted by Rocky Mountain Arsenal (25) (26) (27) (28) (29) (30) (31), Geological Survey (2) (13), Public Health Service (32) (33) (34) (35), Colorado State Department of Public Health (13), and others (36).

During the period of 1943 through September 1955, chemical wastes were conveyed in unlined canals into unlined holding ponds located in Section 25, 35 and 36 of T. 2 S., R. 67 W; the holding ponds were designated as ponds A, B, C, D, E, F and the caustic waste basin (27). Records are not available of total amounts of wastes discharged into these holding ponds. Measurements made in 1955 by Ralph W. Parsons Company (29) showed the average input to the ponds amounted to about 570 gpm at that time. In addition, saline water was discharged into First Creek from the Arsenal's sewage treatment plant, shown on Figure 3. The Geological Survey (13) reported the sewage treatment plant discharged about one to two cfs (449 to 898 gpm) in 1956. Samples collected from First Creek on November 17, 1954, October 6, 1955, and March 9, 1956, showed chloride concentrations were 850, 1,330 and 1,080 ppm, respectively.

Available laboratory analyses (13) (27) indicate the character of wastes at Rocky Mountain Arsenal during the period of 1954-1956. Some of the principal chemical constituents of the wastes are shown in the following tabulation:

Source of Sample	Sampling Date	pH	Cond. µmhos	Parts per million					
				Ca	Na	SO_4	Cl	As	TDS
Sewage Plant Effluent	Mar. 1956	--	5040	--	660	615	1240	--	--
First Creek	Mar. 1956	--	4850	--	650	780	1080	0.04	--
Pond "C"	Nov. 1954	6.6	10100	18	2270	368	3020	0.3	10000
Pond "A" Drainage Ditch	Nov. 1954	9.7	9180	13	2220	369	2050	3.4	6120

M. A. Bauer

Additional contaminants found to be present in the wastes include fluoride and phosphorous (13), and the herbicide, 2,4D (31).

Most of the liquid wastes discharged to the holding ponds percolated directly into the shallow aquifer and moved slowly downgradient in a general northwest direction toward the South Platte River. A large part of the saline discharges from the Arsenal sewage treatment plant entered the shallow aquifer through the bed of First Creek.

The rate of ground-water movement within the contaminated zone varies widely. The 1954-56 Geological Survey study (13) indicates an average rate of movement of about 4,800 feet per year in the aquifer northwest of the Arsenal. The approximate time between initial use of Pond A in 1943 and the first effects of contamination in the Nesom wells (2-67-22bcc) in 1951, located about 2.8 miles northwest, indicate an average velocity of about 1,850 feet per year. A much slower rate of ground-water movement is possible in parts of the Arsenal where the aquifer is relatively thin and probably less permeable.

Figure 5 shows the approximate areal extent of saline contamination in 1964.

(Figure 5 is as follows:)

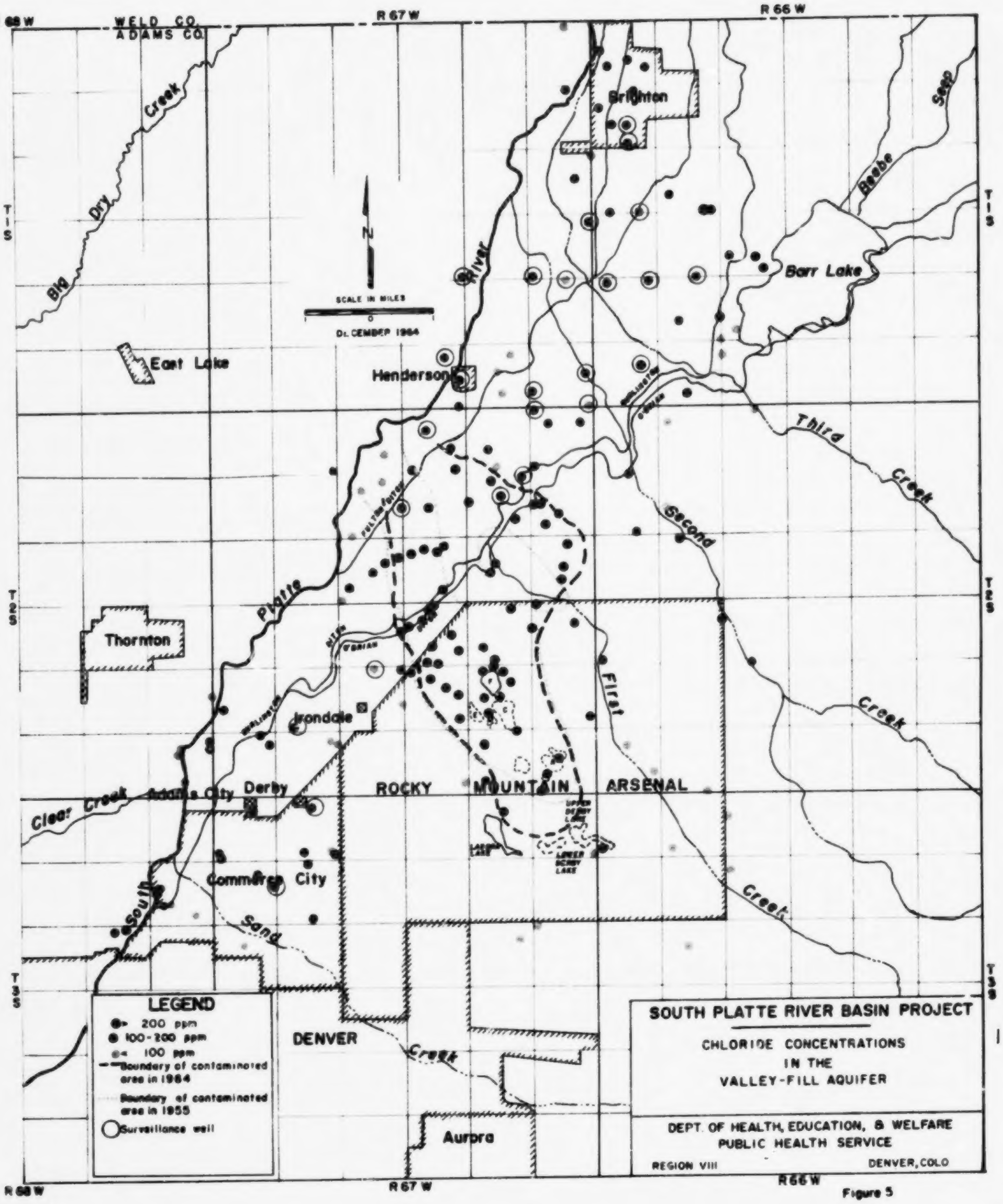

R 68 W
WELD CO.
ADAMS CO.
R 67 W
R 66 W
T 1 S
T 2 S
T 3 S
Big Dry Creek
Brighton
Beebe Seep
Barr Lake
Third Creek
Second Creek
First Creek
Platte River
South Platte
SCALE IN MILES
DECEMBER 1964
East Lake
Henderson
Thornton
Irondale
Clear Creek
Adams City
Derby
Commerce City
Sand Creek
ROCKY MOUNTAIN ARSENAL
UPPER DERBY LAKE
LOWER DERBY LAKE
LADORA LAKE
DENVER
Aurora
LEGEND
● > 200 ppm
● 100-200 ppm
● < 100 ppm
Boundary of contaminated area in 1964
Boundary of contaminated area in 1955
○ Surveillance well
SOUTH PLATTE RIVER BASIN PROJECT
CHLORIDE CONCENTRATIONS IN THE VALLEY-FILL AQUIFER
DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLO

Figure 5

In most cases, waters from shallow wells containing chlorides in excess of 200 ppm were considered to be contaminated (32), although waters from some shallow wells located outside of the contaminated zone do contain chloride concentrations greater than 200 ppm. Waters from shallow wells normally have chloride concentrations ranging from about 50 to 150 ppm. Chloride concentrations of water from shallow wells, shown in Figure 5, are listed in Appendix C. The present area of contamination by high chloride water covers approximately 12 square miles. Since 1955, the east edge of the contaminated zone has moved slowly northward approximately three-fourths of a mile, covering about 2.8 additional square miles. Most of the contaminated water continues to move slowly northwestward in the direction of the natural hydraulic gradient. Movements northward are due to seasonal changes in the hydraulic gradient caused by the pumping of irrigation wells located near the northeast edge of the contaminated zone. Some fluctuations in the width of the zone have occurred in local areas, depending upon amount of pumpage from irrigation wells located in and near the zone. For example, the chloride concentration in water samples collected from the Irondale Trailer Court well, located in the northeast corner of Section 28, T. 2 S., R. 67 W. (2-67-28aaaa) varied from 191 to 220 ppm in 1959; and was 106 ppm in November 1964. The contaminated zone could expand again to the trailer court well, depending upon future distribution of heavy pumpage in this locality.

Chloride concentrations in the contaminated zone continue to be excessive. In 1964, chloride concentrations of well waters commonly exceeded 400 ppm and ranged to as much as 3,075 ppm. Chlorides in the heavily contaminated zone occurring between the abandoned ponds and the O'Brian Ditch ranged from 1,020 to 4,250 ppm in 1956; available analyses indicate chlorides have decreased slightly in this same area to a range of 850 to 3,075 ppm in 1964. Chloride concentrations in the contaminated zone lying northwest of O'Brian's Ditch have remained essentially at the same level of concentration since 1956; chlorides in this locality range from 347 to 1,890 ppm in 1964. The relatively low chloride of waters from several observation wells located near O'Brian and Burlington Ditches is largely due to dilution from seepage in these ditches. Chloride concentrations in the vicinity of Henderson have increased steadily since 1955. Water from a well located in Section 34, T. 1 S., R. 67 W. (1-67-34dad) had a chloride concentration of 97 ppm in 1955. The chloride concentration of water from a nearby well (1-67-34daad) was 137 ppm in 1964.

A substantial decrease in chloride concentration in the aquifer has occurred in the vicinity of the Pond F. Chlorides in water from observation well 2-67-26baad decreased from about 3,080 ppm in 1955 to 766 ppm in 1964. This decrease resulted from recharge water being introduced into the aquifer by filling abandoned ponds C, D and E with about 400 million gallons of fresh water reportedly some time during a two-year period between 1957 and 1959. However, chloride concentrations in the vicinity of ponds C, D and E were as great as 4,205 ppm in 1962, indicating this fresh water in this locality was displaced by the inflow of contaminated ground water from the southeast. As shown in Figure 5, a chloride concentration of 2,220 ppm in a water sample taken recently from an observation well (3-67-2acbc), located near the north shore of Lake Ladora, indicates the possibility that wastes may have been discharged at one time into one of the three lakes located southeast of the well. A chloride concentration of 244 ppm found in a sample taken in 1956 from a well located on the south shore of upper Derby Lake (3-66-6ccb) indicates waste water has been discharged at one time into this lake.

Significant concentrations of arsenic were found in the locality immediately northwest of the

Arsenal's ponds C, D, E and F. Analyses of samples taken from test wells during the 1954-1956 Geological Survey study (13) show arsenic concentrations ranged from 0.01 to 0.09 ppm. The present extent of arsenic in the contaminated zone is not known. A recent sample of water from an observation well (2-67-26bbad) located on the northwest shore of Pond F shows an arsenic concentration of 0.01 ppm. However, arsenic has not been detected in two contaminated sampling wells located at distances of about 1.5 miles north and northwest from the Arsenal.

Concentrations of fluoride ranging from 1.6 to 5.6 ppm were found in waters from 24 wells during the 1954-56 Geological Survey study. Most of these wells are located in the heavily contaminated zone underlying the arsenal. A concentration of 9.7 ppm was detected recently in observation well No. 62 (2-67-26bbad) located near Pond F. A fluoride concentration of 1.7 ppm detected in Surveillance Well XIV (2-67-9daac) indicates excessive fluorides may exist in the contaminated area northwest of the Arsenal. The use of fluoride concentrations as a sole indicator of Arsenal contamination is uncertain, since fluorides ranging from 0.5 to 1.6 often occur in water wells located outside the contaminated zone.

An investigation of plant toxicants in well water was conducted by the University of Colorado between 1956 and 1960 (23) (24). Chlorate concentrations of up to about 20 ppm were found in waters from 34 wells. A plant toxicant similar to the herbicide 2,4-D was also found in waters from 33 wells. Studies of water from more than 225 wells show the area affected by these plant toxicants closely conforms to the area of the chloride contamination delinated by studies of the Geological Survey in 1955 and 1956.

Investigation of the duck kill problem on the Arsenal by the United States Fish and Wildlife Service (37) revealed significant concentrations of pesticides in the soils underlying Lake Ladora, upper Derby Lake and lower Derby Lake. In 1964 the Arsenal reported the upper 6 to 24 inches of contaminated soils in these lakes were being removed and stored in the northeast quarter of Section 12, T. 3 S., R. 67 W. The contaminated waste pile will be covered with soil and will not be subject to surface run-off. However, since the waste pile is located on the outcrop of the valley-fill aquifer, there is a possibility of contamination of the shallow aquifer from leaching by direct precipitation on the covered waste pile.

Analyses of waters from sampling wells on the Arsenal property indicate the contaminated zone contains pesticides. Samples collected from three wells in July 1964 were analyzed by the U. S. Fish and Wildlife Service at Denver, Colorado, for aldrin, dieldrin and endrin, using gas chromatography (38). Aldrin and dieldrin were detected. Results of these analyses are shown in the following tabulation:

RMA Well No.	Location (T-R-Sec.)	Well Depth (ft)	Sampling Date	Portion of Sample Analyzed	Aldrin	Dieldrin
3-A	2-67-26baba	39	7/28/64	Filtered Water	0.026 ppb a/	0.071 ppb
				Suspended Solids	0.1 ppm	6.5 ppm
22	3-67-1cbac	20	7/28/64	Filtered Water	< 0.01 ppb	0.053 ppb
				Suspended Solids	0.132 ppm	0.6 ppm
109	3-67-2acbc	30	7/28/64	Filtered Water	0.024 ppb	0.037 ppb
				Suspended Solids	---	0.6 ppm

---

a/ ppb denotes parts per billion.

M. A. Bauer

Available records show 64 domestic, stock and irrigation wells have been affected by contamination. The Federal Government has paid approximately $165,000 to date on 27 damage claims for crop and ground-water supply losses. Six additional damage claims are pending.

Contamination of the aquifer is likely to persist for many decades if the trend of relatively small decreases in chloride concentrations continues. The continued high degree of saline contamination may be due to continuing contamination from possible sludge accumulations beneath some of the abandoned disposal ponds, or may be due to relatively slow movements of ground water on the Arsenal property because of the low permeability of aquifer in the heavily contaminated parts of this area. A pit excavated recently in abandoned Pond A to a depth of three feet did not reveal shallow sludge accumulations.

Several continuous cores of the interval between the pond bottom and the base of the aquifer are needed in each abandoned holding pond to determine whether sludge deposits occur at deeper depths. Pumping tests should be conducted on several wells located in the thinner and probably less permeable areas of the contaminated zone on the arsenal. Results of these tests could be used to determine rates of ground-water movement in the heavily contaminated area.

The effect of the contaminated ground-water on the quality of water in the South Platte River was evaluated. As the contaminated water moves downgradient in a northwesterly direction, the chloride concentration is reduced considerably by seepage from Burlington, O'Brian and Fulton ditches and ditch water applied on irrigated farms. The contaminated water continues to move downgradient until it is diluted further by the larger main body of ground-water flow beneath the flood plain of the South Platte River. This diluted water continues to move downvalley and discharges as ground-water return flow into the river in the vicinity of Henderson. Records of chemical analyses of South Platte River water at Henderson and at sampling stations located upstream (2) (9) (10) (11) (12) (13) (39) do not indicate the salt load contributed to the river by ground-water return flow originating from contamination on the Arsenal. However, considering the great amount of dilution in the aquifer occurring from ditch water seepage and ground-water inflow prior to discharging into the river, it is unlikely that salts originating in the contaminated zone are causing significant increases in the salinity of the river water.

Excessive chloride concentrations have been found in water samples collected from three deep wells screened in the bedrock aquifers. It is concluded that since these wells are located within the boundary of the contaminated zone, saline water has probably entered these wells through openings in the casing or through the annulus between the casing and hole. Pertinent information on these deep wells is shown in the following tabulation:

Owner	Location (T-R-Sec.)	Well Depth (ft)	Chloride (ppm)	Sampling Date
L. Baughman	2-67-9ddc	205	222	10/30/59
E. Tiedeman	2-67-14ccdb	450	385	3/8/56
Rocky Mountain Arsenal	2-67-22acdc	178	290	5/13/64

Contamination of the bedrock aquifers probably occurs only in the immediate vicinity of these defective wells. Widespread contamination of the bedrock aquifers from these defective wells is unlikely owing to the very slow rate of movement of ground water in the bedrock aquifers. However, the number of defective deep wells possibly affected by saline contamination at the present time is unknown. Records of the Geological Survey (3) and the State Engineer of Colorado show 61 deep wells are located in and near the boundary of the contaminated zone of the shallow valley-fill aquifer; relatively few of these deep water wells have been sampled since 1959.

Some shallow wells located outside of the contaminated zone yield water having chloride concentrations in excess of 200 ppm. As shown in Figure 5, most of these wells are located in the vicinity of Second Creek and in the locality southeast of Brighton. Pertinent information relating to these wells is shown in Table V.

(Table V is as follows:)

TABLE V

INFORMATION ON SELECTED WELLS

Well Location (T-R-Sec.)	Well Depth (ft)	Depth to Bedrock (ft)	Use of Well[a/]	Sampling Date	Specific Con-ductance	Calcium (ppm)	Sodium (ppm)	Bicar-bonate (ppm)	Sul-fate (ppm)	Chlo-ride (ppm)	Total Dissolved Solids (ppm)
1-66-17ddcd	38	32	S	11/23/64	3700	248	390	593	1070	295	2720
1-66-17ddcc	35	32	L.I.	11/23/64	2600	144	332	549	636	202	1770
1-66-21ccc	50	10	D	11/9/64	2570	224	250	303	793	204	1950
1-66-21dca	40	35	D	5/20/63	--	--	--	--	--	248	--
1-66-29dada	30	20	D,S	11/24/64	2440	196	235	503	330	245	1610
1-66-31acad	50	15	D	11/18/64	5510	284	940	354	1930	375	4490
2-66-17baba	30	20	N,O	11/18/64	6090	521	850	471	2480	402	4980
2-66-20adad	19	19	N,O	11/17/64	4780	461	375	329	1200	210	4530

[a/] D - Domestic; L.I. - Lawn Irrigation; N - Not used; O - Observation purposes; S - Stock.

These wells yield calcium sulfate or sodium sulfate type waters. Well records of the Geological Survey (3) show gypsum (hydrous calcium sulfate) fragments occur in the silty bedrock materials near the base of the valley-fill deposits. As shown in Table V, the depth of most of the shallow wells is below the base of the valley-fill deposits, indicating the water produced is derived from both formations. The relatively high sulfate and chloride concentrations in these waters is attributed to effects of soluble gypsum and small amounts of associated salts. Waters produced from nearby wells that are screened only in the valley-fill deposits contain considerably lower concentrations of chloride and sulfate.

Current Disposal Practices of Rocky Mountain Arsenal

Since 1957, all industrial wastes have been conveyed to Pond F by pipeline or by tank truck. The 96-acre asphalt-lined reservoir has a capacity of 240 million gallons. Liquids have been removed from the pond by evaporation and by injection into a deep underground disposal well. Records of amounts of liquid wastes discharged to and removed from Pond F during the period of February 1961 through May 1964 are summarized in the following tabulation:

Pond spill point elevation, feet	5,200.00
Fluid Elevation, ft., Feb. 1, 1961	5,198.78
Fluid Elevation, ft., May 28, 1964	5,197.33
Fluid level decline, ft.	1.45

Net decrease in pond fluid, gallons	45,000,000
Input of plant wastes, gallons	247,000,000
Measured precipitation, gallons	67,100,000

Evaporation, gallons	259,100,000
Injected in disposal well, gallons	100,000,000
Total output	359,100,000

Records of precipitation and evaporation from the U. S. Weather Bureau were used to evaluate the reported information on Pond F during this period. Because quantities of precipitation and evaporation are only approximate, the monitoring of input and output from Pond F would only reveal large amounts of leakage which did not occur in this case.

Four observation wells, located near the north shore of the Pond F, are monitored for the purpose of detecting leakage from the reservoir. Water level measurements taken in 1962 and 1964 do not reveal rises in the water table that can be related to leakage from the pond. Water samples are currently obtained from these observation wells on a weekly basis for chloride determination. Chlorides in water from Well No. 118 (2-67-26-bada) have increased sharply in recent months. In samples collected from this well during the months of March through May, 1964, chlorides ranged from 520 to 790 ppm; during June through November 1964, chlorides ranged from 1,160 to 1,640 ppm. Chloride concentrations in samples from nearby observation wells No. 3A (2-67-26baad), No. 72 (2-67-23cddc) and No. 62 (2-67-26-bbad) have remained essentially constant during 1964.

In view of the previous contamination, data collected by the Arsenal to date from the observation wells near Pond F would not reveal small amounts of leakage. The water-bearing formation underlying the vicinity of the pond should be completely displaced by water having a chloride concentration of about 100 ppm. Displacement could be accomplished by introducing low chloride water into the aquifer by water spreading in the locality south and east of the pond. This would then permit detection of significant changes in chloride concentrations in the aquifer in the vicinity of the pond. The well monitoring program should also include the utilization of other existing observation wells located near the perimeter of Pond F in order to determine whether increases in chlorides would be due to pond leakage or inflow of older contaminated water.

From March 1962 through September 1963, about 100 million gallons of filtered liquid from Pond F were injected into a deep disposal well located immediately northeast of the pond in Section 26. Throughout this period, well head injection pressures were reported to vary from 425 to 630 pounds per square inch (psi) at injection rates of about 200 gpm. The well and two piston-type injection pumps were designed to inject fluids at well head pressures of up to 2,000 psi.

During the period of November 1963 to November 1964, only small amounts of wastes were injected into the disposal well, reportedly because of the relatively high costs of filtering the concentrated pond liquids and operating the high-capacity piston-type injection pumps. Pond F. was modified in November 1964 by constructing an earthen embankment across a portion of the reservoir, separating "fresh" industrial wastes from the older concentrated pond liquids. Currently, filtered "fresh" industrial wastes are injected into the disposal well at a rate of about 50 gpm at a well head pressure of about

60 psi. The Arsenal plans to install a larger centrifugal pump capable of injecting at rates of about 200 gpm. Approximately 145 gpm of industrial wastes are currently discharged into Pond F.

This possibility of contaminating the fresh water sands from the disposal of wastes in the injection well is remote. The pond fluid is injected in highly fractured Pre-Cambrian granites occurring between the depths of 11,975 and 12,045 feet below the ground surface (39) (40). The well is cased and cemented to a depth of 11,171 feet below the surface. In addition, a larger diameter casing is set and cemented to a depth of 2,000 feet in order to assure protection of the fresh-water-bearing formations that occur above 1,430 feet. Electrical logs and descriptions of the drill cuttings from the hole show the interval between 1,430 and 11,950 feet below the land surface is composed largely of great thicknesses of shale, siltstone, hard sandstone and dense limestone.

Well Monitoring Programs

Since 1959, the Colorado State Department of Public Health and Tri-County Health Department have maintained a well-monitoring program for the purpose of keeping currently informed on direction and rate of movement of the contaminated water. Water samples are currently obtained every seven months from 25 surveillance wells. Locations of the surveillance wells are shown in Figure 5 and recent chemical analyses of waters from these wells are shown in Appendix B. Many additional water samples have been collected from private wells in the area by the Tri-County Health Department. The Rocky Mountain Arsenal currently collects water samples for chloride determination from 7 observation wells on a weekly basis and from an additional 7 wells on a monthly basis, and periodically obtains water samples from numerous observation wells and private wells in the area. Reports of chemical analyses are made available to all agencies concerned with the contamination problem. Well owners are notified by the Tri-County Health Department when chloride concentrations exceed 200 ppm. However, in each instance, it should be determined whether excessive chlorides in well waters are due to movements of contaminated water, or due to natural causes such as effects of soluble evaporite materials occurring in the water-bearing formation.

The well-monitoring programs of the Tri-County Health Department and Colorado State Department of Public Health, and the Rocky Mountain Arsenal provide adequate information on changes in chemical quality in most areas lying north of the contaminated zone. However, additional sampling wells are needed along and immediately outside of the east and west edges of the contaminated zone, in order to determine, more closely, the extent of contamination.

Records of the State Engineer of Colorado and the Geological Survey show 61 deep wells are located in and near the present boundary of the contaminated zone of the valley-fill aquifer. Water samples should be obtained periodically from all these wells for chemical analyses in order to detect possible leakage resulting from defective casings or improper cementing.

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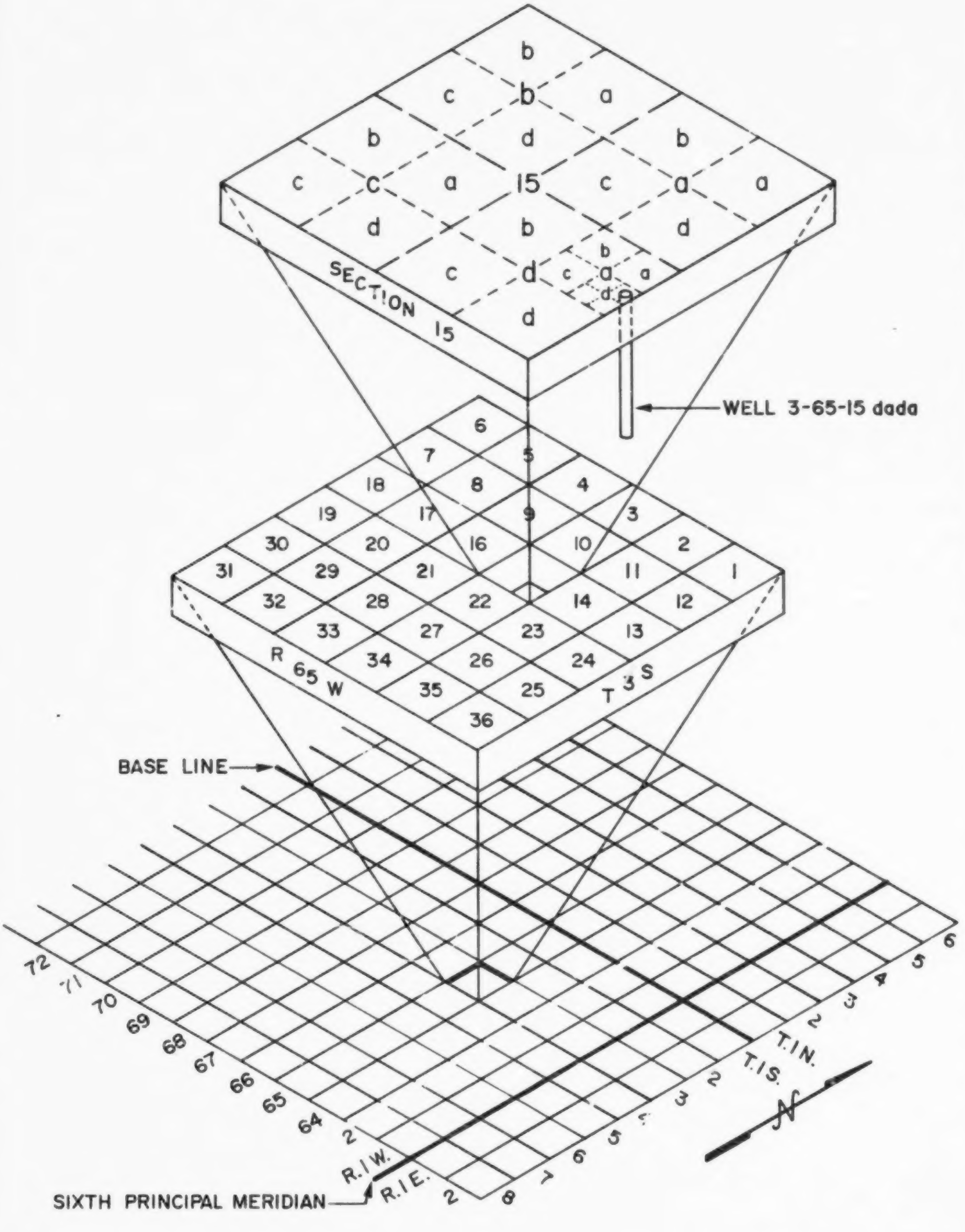
APPENDIX A

SYSTEM OF NUMBERING WELLS & SAMPLING POINTS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SECTION 15
WELL 3-65-15 dada
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T 3 S
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BASE LINE
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R.1E.
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T.1S.
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SIXTH PRINCIPAL MERIDIAN

APPENDIX B

Chemical Analysis of Water
(Results in Parts per Million)

Location (T-R-Sec)	Owner	Use of Water a/	Well Depth (ft.)	Sampling Date	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Sodium (Na)	Sulfate (SO_4)	Chloride (Cl)	Bicarbonate (HCO_3)	Fluoride	Total Phosphate (PO_4)	Nitrate (NO_3)	ABS	Total Dissolved Solids	Total Alkalinity as $CaCO_3$	Hardness as $CaCO_3$	Conductance Micromhos/cm	pH	Analyst b/	Remarks c/
1-66-6cbdd	Brighton #8	P.S.	35	11/9/64	0.11	0.0	136	155	308	120	346	--	--	62.9	0.1	1060	284	476	1580	7.1	P	
1-66-6dacd	Brighton #6	P.S.	50	6/3/64	--	--	--	--	--	124	--	--	--	72	0.0	--	--	--	--	--	C	
1-66-6dbbc	Brighton #10	P.S.	42	6/3/64	--	--	--	--	--	125	--	--	--	69	0.0	--	--	--	--	--	C	
1-66-7abac	Brighton #4	P.S.	33	6/3/64	--	--	--	--	--	144	--	--	--	55	0.1	--	--	--	--	--	C	
1-66-7abb	Brighton #1, 2, 3	P.S.	40,50,40	11/5/43	--	--	138	134	332	91	--	--	--	32	--	999	--	--	--	7.9	U	Composite Sample
1-66-7abb	Brighton #1, 2, 3	P.S.	40,50,40	11/9/64	0.19	0.0	146	145	302	132	346	--	--	62.9	0.1	1060	284	516	1590	7.2	P	Composite Sample
1-66-7bcbd	Brighton #13	P.S.	65	6/3/64	--	--	--	--	--	125	--	--	--	62	0.0	--	--	--	--	--	C	
1-66-7cabc	Brighton #12	P.S.	66	6/3/64	--	--	--	--	--	113	--	--	--	71	0.0	--	--	--	--	--	C	
1-66-7dbcb	Brighton #7	P.S.	55	11/9/64	0.11	0.0	144	145	300	129	371	--	--	62.9	0.1	1110	304	516	1600	7.3	P	I
1-66-7dccb	Brighton #11	P.S.	62	11/9/64	0.16	0.0	150	140	296	138	356	--	--	64.7	0.1	1090	292	520	1590	7.4	P	II
1-66-17cbdc	L. Darras	I	28	11/23/64	0.21	0.0	115	113	268	128	329	--	--	82.9	0.2	976	270	472	1140	7.8	P	
1-66-17ddcd	S. Kuster	S	38	11/23/64	0.19	0.0	248	390	1070	295	593	--	--	43.2	0.1	2720	486	1040	3700	7.8	P	
1-66-17ddcc	S. Kuster	L.I.	35	11/23/64	1.46	0.0	144	332	636	202	549	--	--	44.7	0.2	1770	450	600	2600	7.8	P	
1-66-18dcdd	B. Wagner	S	35	8/12/64	0.2	0.0	173	130	226	105	200	1.1	0.0	35	0.09	724	164	277	1100	--	C	XXV
1-66-20dccd	V. Amdahl	L.I.	20	1-6-64	0.05	0.0	336	160	230	142	400	1.3	0.0	34	0.08	1050	328	463	1470	--	C	VI
1-66-21cad	Barr Lake Inn	D	50	11/9/64	0.11	0.0	224	250	793	204	303	--	--	89.5	0.3	1950	248	787	2570	7.1	P	
1-66-29dada	E. Mowery	D	30	11/24/64	0.04	1.25	196	235	330	245	503	--	--	2.6	0.1	1610	412	710	2440	7.6	P	
1-66-29dddd	E. Mowery	I	30	7/12/64	--	--	--	--	--	87	--	--	--	--	--	--	--	--	--	--	P	
1-66-30aaab	G. Hoffman	D	50	8/12/64	0.08	0.0	205	140	313	120	224	1.2	0.0	7	0.0	854	184	352	1285	--	C	VII
1-66-30bbab	H. Shreeve	S, L.I.	20	1/6/64	0.05	0.0	344	124	230	107	356	0.65	--	25	0.0	897	292	443	1262	--	C	IV
1-66-31acad	E. Potter	D	50	11/18/64	--	--	284	940	1930	375	354	--	--	11.4	0.3	4490	290	1240	5510	7.3	P	XXIV
1-67-22dddd	W. Kemp	D,S	60	8/11/64	0.05	0.0	252	150	362	92	210	1.3	0.5	41	0.1	943	172	455	1378	--	C	XVI
1-67-24aaad	G. Okubo	D	30	8/12/64	0.08	0.0	343	125	275	117	356	0.8	0.0	40.5	0.09	934	292	475	1370	--	C	XXVI
1-67-24cccc	J. Tochihara	D	50	1/6/64	0.15	0.0	440	124	265	120	420	0.55	--	35	0.0	1024	344	557	1431	--	C	III
1-67-25abbb	L. Ehlen	S	33	8/11/64	0.05	0.0	327	150	358	90	190	0.7	0.0	41.5	0.1	1043	156	475	1545	--	C	V
1-67-34abdc	F. Nyholt	D	12	8/11/64	0.05	0.0	347	180	489	118	303	1.6	0.0	16	0.1	1165	248	475	1645	--	C	XVIII
1-67-34daab	R. Miller	D	18	1/6/64	0.15	0.0	400	125	282	137	361	0.8	--	76	0.05	1062	296	557	1470	--	C	XIX
1-67-36adcd	J. Erger	D	20	1/6/64	0.05	0.0	420	158	299	158	454	0.6	--	00.0	0.18	1101	372	549	1555	--	C	XXIII
1-67-36cbcc	C. Shaw	D	38	8/11/64	0.08	0.0	233	114	236	129	210	1.1	0.0	78.0	0.2	316	172	408	1250	--	C	VIII
1-67-36ddcd	H. Manley	S	40	8/11/64	0.0	0.0	252	93	191	97	298	0.7	0.0	29	0.07	719	244	360	1089	--	C	XXII
2-66-5caa	E. Kallsen	S	42	11/23/64	1.23	0.0	62	125	162	30	356	--	--	51	0.1	664	292	230	1020	7.8	P	

APPENDIX B

Chemical Analysis of Water (Continued)

Location (T-R-Sec)	Owner	Use of Water a/	Well Depth (ft.)	Sampling Date	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Sodium (Na)	Sulfate (SO$_4$)	Chloride (Cl)	Bicarbonate (HCO$_3$)	Fluoride	Total Phosphate (PO$_4$)	Nitrate (NO$_3$)	ABS	Total Dissolved Solids	Total Alkalinity as CaCO$_3$	Hardness as CaCO$_3$	Conductance Micromhos/cm	pH	Analyst b/	Remarks c/
2-66-7abbb	RMA #52	N, O	25	11/18/64	--	--	316	260	1030	155	349	--	--	10.7	0.1	2390	286	1100	2860	7.2	P	
2-66-7dcdc	S. Wawok	D	55	11/23/64	0.92	0.0	98	200	492	128	264	--	--	82.9	0.2	1280	216	408	1860	8.0	P	
2-66-17baba	RMA #53	N. C	30	11/18/64	--	--	521	850	2480	402	471	--	--	0.8	0.3	4980	386	1870	6090	7.2	P	
2-66-20adad	RMA #47	N, O	22	11/17/64	--	--	461	375	1200	210	329	--	--	0.3	0.1	4530	270	1800	4780	7.4	P	
2-66-21cddc	RMA #54	N, O	30	11/18/64	--	--	332	495	1490	142	490	--	--	3.5	0.2	3400	402	1260	3860	7.1	P	
2-66-31bdaa	RMA #20	N, O	28	11/17/64	--	--	52	100	246	46	283	--	--	0.0	0.1	560	232	234	862	7.9	P	
2-67-1bbbb	J. Salthouse	D	46	8/11/64	0.08	0.0	244	115	240	134	234	0.9	0.0	59.	0.13	845	192	396	1236	--	C	XII
2-67-3bdbd	J. Himes	S, I	32	8/12/64	0.05	0.0	232	118	232	112	249	1.0	0.0	30.	0.07	763	204	348	1064	--	C	XX
2-67-4dbdc	RMA #55	N, O	30	11/18/64	--	--	81	100	132	68	354	--	--	0.2	0.8	679	290	325	1060	7.4	P	
2-67-9bdba	RMA #56	N, O	30	11/18/64	--	--	81	85	85	78	346	--	--	0.7	1.0	578	284	284	913	7.6	P	
2-67-9daac	E. Aden	I	30	8/12/64	0.05	0.0	630	225	407	625	210	1.7	--	32.5	0.17	2009	172	939	2838	--	C	XIV
2-67-11aaba	J. Fry, Sr.	S	44	8/11/64	0.2	0.0	244	122	245	149	213	0.6	0.0	45.	0.13	890	224	420	1345	--	C	XIII
2-67-11bdad	B. Murray	I	60	8/11/64	0.05	0.0	402	175	342	310	234	1.0	0.0	30.5	0.18	1301	192	614	1972		C	XXI
2-67-11daaa	RMA #113	N, O	54	11/18/64	--	--	316	265	750	352	381	0.9	4.47	9.3	0.3	2320	312	1100	3020	7.0	P	As 0.0, COD 21
2-67-13dccc	----	---	---	11/23/64	0.32	0.0	131	140	465	125	212	--	--	12.8	0.2	1120	174	490	1590	8.4	P	First Creek
2-67-25ddab	RMA #61	N, O	12	11/17/64	--	--	106	175	410	114	290	--	--	0.09	0.1	1100	238	455	1570	7.6	P	
2-67-26baba	RMA #3A	N, O	39	11/17/64	--	--	45	690	268	766	915	--	--	0.11	0.4	2330	750	228	3860	7.8	P	
2-67-26bada	RMA #118	N, O	39	11/17/64	--	--	300	660	301	1550	939	--	--	0.2	1.1	4300	770	1600	6160	7.0	P	
2-67-26bad	RMA Pond F	--	--	10/14/64	--	--	--	--	--	--	--	--	--	29.0	--	20968	---	---	---	8.4	R	COD 6241, DO 1.2
2-67-26badc	RMA Pond F	--	--	11/17/64	--	--	112	7600	615	7280	5880	--	--	--	--	22700	4820	610	27500	8.4	P	
2-67-26bbad	RMA #67	N, O	51	11/17/64	--	--	34	540	408	350	578	9.7	9.58	0.1	0.1	1740	474	202	2790	7.6	P	As 0.01, COD 25
2-67-28aaaa	Irondale Trailer Court	P.S.	51	11/12/64	0.12	0.0	71	110	139	106	222	--	--	2.1	0.0	604	182	265	983	7.6	P	
2-67-28abb	A. Hessling	D, I	50	1/6/64	0.10	0.0	344	65	249	45	268	0.5	--	21.	0.0	717	220	424	1022	--	C	XX
2-67-29cdc	S. Adams WSD #2 (S-9)	P.S.	80	11/12/64	0.12	0.0	196	150	359	119	381	--	--	50.1	0.1	1160	312	590	1620	7.4	P	X
2-67-32adc	S. Adams WSD #2 (S-8)	P.S.	100	11/12/64	0.0	0.0	140	62	248	50	254	--	--	18.4	0.00	71	208	420	1020	7.7	P	
2-67-32adc	S. Adams WSD #3	P.S.	93	11/12/64	0.09	0.0	174	120	318	97	350	--	--	28.2	0.1	991	288	525	1430	7.6	P	

APPENDIX B

Chemical Analysis of Water (Continued)

Location (T-R-Sec)	Owner	Use of Water a/	Well Depth (ft)	Sampling Date	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Sodium (Na)	Sulfate (SO_4)	Chloride (Cl)	Bicarbonate (HCO_3)	Fluoride	Total Phosphate (PO_4)	Nitrate (NO_3)	ABS	Total Dissolved Solids	Total Alkalinity as $CaCO_3$	Hardness as $CaCO_3$	Conductance Micromhos/cm	pH	Analyst b/	Remarks c/
2-68-25daaa	Thornton #5	P. S.	26	11/16/64	0.3	0.0	164	98	227	56	224	--	--	0.3	0.2	643	184	252	983	7.2	P	
2-68-36aada	Thornton #12	P. S.	29	11/16/64	0.14	0.17	125	165	334	178	268	--	--	0.3	0.1	1040	220	388	1570	7.6	P	
2-68-36aadd	Thornton #15	P. S.	29	11/16/64	0.13	0.02	114	170	353	180	261	--	--	0.3	0.1	1040	214	374	1560	7.8	P	
2-68-36bdaa	N. Washington WSD #1	P. S.	18	11/9/64	0.0	0.13	126	115	246	52	381	--	--	40.4	0.0	848	312	400	1250	7.2	P	325' gallery
2-68-36bdad	N. Washington WSD #2	P. S.	25	11/9/64	0.0	0.08	89	155	366	19	322	--	--	29.8	0.1	939	264	250	1330	7.4	P	925' gallery
2-68-36dcbc	N. W. Water Corp	P. S.	30	11/9/64	0.23	1.00	69	95	246	20	210	--	--	7.1	0.5	636	172	268	940	7.0	P	
3-67-1dddd	RMA #10	N, O	77	11/17/64	--	--	83	91	272	49	306	--	--	0.3	0.0	600	251	275	913	7.8	P	
3-67-2acbc	RMA #109	N, O	30	11/17/64	--	--	116	1820	884	2020	165	0.8	2.06	0.5	0.3	6370	135	430	9560	7.5	P	As 0.0, COD 131
3-67-2cab	RMA -Lake Ladora	--	--	11/17/64	--	--	116	100	307	116	161	--	--	0.0	0.0	790	132	380	1240	8.4	P	
3-67-5abcd	S. Adams WSD #2 (S-7)	P.S.	80	11/12/64	0.05	0.0	188	160	374	123	364	--	--	50.1	0.1	1190	302	560	1670	7.4	P	IX
3-67-5dddd	S. Adams WSD #2 (S-5)	P.S.	80	11/12/64	0.10	0.0	160	150	341	92	342	--	--	23.6	0.9	1010	280	470	1430	7.4	P	
3-67-5dddd	S. Adams WSD #3 (S-6)	P.S.	80	11/12/64	0.14	0.0	168	145	355	103	361	--	--	30.7	0.9	1080	296	505	1540	7.4	P	
3-67-6ab	R. E. Murfine	--	32	11/5/43	--	--	178	63	433	102	--	--	--	48.	--	1107	--	--	--	7.9	U	
3-67-6ccdc	S. Adams WSD #2 (S-2)	P.S.	43	11/12/64	0.02	0.0	150	155	300	123	376	--	--	20.2	0.9	1020	308	465	1570	7.2	P	
3-67-6ccdc	S. Adams WSD #3 (S-3)	P.S.	45	11/12/64	0.07	0.08	144	160	304	141	388	--	--	7.3	1.0	1040	318	445	1570	7.2	P	
3-67-7acaa	Town & Country #2	P.S.	22	11/24/64	7.64	1.91	188	100	533	142	224	--	--	0.2	0.1	1510	184	600	1930	6.6	P	Phenol 0.0 Oil 2.0
3-67-7addd	Town & Country #1	P.S.	42	11/24/64	0.01	1.16	176	175	453	148	522	--	--	5.9	0.6	1220	428	570	1760	7.8	P	Phenol 0.0, Oil 2.0 XI

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a/ D - Domestic; I - Irrigation; L.I. - Lawn Irrigation; N - Not used; O - Observation purposes; P.S. - Public Supply; S - Stock.

b/ C - Colorado State Department of Public Health; P - U. S. Public Health Service; R - U. S. Army Rocky Mountain Arsenal; U - Colorado State University

c/ Roman Numeral designates surveillance well monitored by Tri-County Health Department.

APPENDIX C

CHLORIDE CONCENTRATION OF WATER FROM WELLS SHOWN IN FIGURE 5

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
1-66-6cba	Kuner-Empson	C,P	30	8/12/63	130	C
1-66-6cbdd	Brighton #8	P.S.	35	11/9/64	120	P
1-66-6dacd	Brighton #6	P.S.	50	6/3/64	124	C
1-66-6dbbc	Brighton #10	P.S.	42	6/3/64	125	C
1-66-7abac	Brighton #4	P.S.	33	6/3/64	144	C
1-66-7abb	Brighton #1, 2,3	P.S.	40,50 40	11/9/64	132[c]	P
1-66-7bcbd	Brighton #13	P.S.	65	6/3/64	125	C
1-66-7cabc	Brighton #12	P.S.	66	6/3/64	113	C
1-66-7dbcb	Brighton #7	P.S.	55	11/9/64	129	P
1-66-7dccb	Brighton #11	P.S.	62	11/9/64	138	P
1-66-17cbdc	L. Darras	I	28	11/23/64	128	P
1-66-17ddcd	S. Kuster	S	38	11/23/64	295	P
1-66-17ddcc	S. Kuster	L.I.	35	11/23/64	202	P
1-66-18cdcc	A. Hattendorf	D	40	4/5/62	106	G
1-66-18dcdd	B. Wagner	S	35	8/12/64	105	C
1-66-20dccd	V. Amdahl	L.I.	20	1/6/64	142	C
1-66-21cad	Barr Lake Inn	D	50	11/9/64	204	P
1-66-21cbc	J. Candelarie	D	60	5/15/63	184	C
1-66-21dcb	M. Espinosa	D	40	5/20/63	248	C
1-66-28ccb	W. Pollard	D	40	2/3/64	79	C
1-66-29cac	---	I,S	45	4/5/62	119	G
1-66-29dada	E. Mowery	D	30	11/24/64	245	P
1-66-29dddd	E. Mowery	I	30	7/12/64	87	P
1-66-30aaab	G. Hoffman	D	50	8/12/64	120	C
1-66-30bbab	H. Shreeve	S,L.I.	20	1/6/64	107	C
2-67-29cdc	So. Adams WSD No. 2(S-9)	P.S.	80	11/12/64	119	P
2-67-30cbd	Kinney	H	30	7/31/63	118	C
2-67-31aabb	Sausd	--	--	8/7/63	114	C
2-67-31aadc	I. Haberhorn	--	--	3/4/64	119	C

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
2-67-32aad	S. Adams WSD #2(S-8)	P.S.	100	8/12/64	50	P
2-67-32aad	S. Adams WSD #3	P.S.	93	8/12/64	97	P
2-67-35abaa	RMA #5	N,O	55	5/20/64	1930	R
2-67-35bca	RMA	N,O	45	12/8/59	3117	R
2-67-35cca	RMA	N,O	48	12/8/59	125	R
2-67-36bdc	RMA #40	N,O	42	2/16/60	2278	R
2-67-36cbdd	RMA #7	N,O	36	6/14/62	1518	R
2-67-36ccdd	RMA #81A	N,O	31	6/14/62	382	R
2-68-25daaa	Thornton #5	P.S.	26	11/16/64	56	P
2-68-36aada	Thornton #12	P.S.	29	11/16/64	178	P
2-68-36aadd	Thornton #15	P.S.	29	11/16/64	180	P
2-68-36bdaa	N. Wash WSD #1 Gallery	P.S.	18	11/9/64	52	P
2-68-36bdad	N. Wash. WSD #2 Gallery	P.S.	25	11/9/64	19	P
2-68-36dcbc	NW Water Corp	P.S.	30	11/9/64	20	P
3-66-4bccb	H. Hendler	I	18	1/1/55	52	G
3-66-5ccd	--	N	20	7/28/64	86	P
3-66-6cccb	RMA	N	46	10/4/55	228	G
3-66-8daaa	RMA	N	15	10/4/55	39	G
1-66-31acad	E. Potter	D	50	11/18/64	375	P
1-66-32aadd	M. Dahlinger	S	16	4/5/62	85	G
1-66-32cdaa	G. Reasoner	N	19	2/4/60	188	R
1-67-1abbb	E. Getz	D	30	4/18/63	98	C
1-67-12abba	R. Pfeif	D	30	4/18/63	115	C
1-67-13aaa	M. Tesbero	D	42	6/18/63	95	C
1-67-13acdd	G. Quick	D	35	4/5/62	116	G
1-67-22dddd	W. Kemp	D,S	60	8/11/64	92	C

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
1-67-24aaad	G. Okubo	D	30	8/12/64	117	C
1-67-24cccc	J. Tochihara	D	50	1/6/64	120	C
1-67-25abbb	L. Ehlen	S	33	8/11/64	90	C
1-67-34abdc	F. Nyholt	D	12	8/11/64	118	C
1-67-34daab	R. Miller	D	18	1/1/64	137	C
1-67-34ddcd	A. Adams	I	10	6/10/63	117	C
1-67-35abd	W. Johnston	D	--	6/24/64	93	C
1-67-35bddd	C. Griffith	I	40	7/15/63	90	C
1-67-35dcbb	J. Carlson	--	32	4/18/63	87	C
1-67-36adcd	J. Erger	I	20	1/6/64	158	C
1-67-36cbcc	C. Shaw	D	33	8/11/64	129	C
1-67-36ddcb	H. Manley	I	30	8/11/64	97	C
2-66-4baa	E. Dahlinger	S	20	2/1/60	43	R
2-66-5caa	E. Kailsen	S	42	11/23/64	30	P
2-66-7abbb	RMA #52	N,O	25	11/18/64	155	P
2-66-7dcdc	S. Wawok	D	55	11/23/64	128	P
2-66-8cbb	W. Longaker	N	50	8/11/64	47	P
2-66-17baba	RMA #53	N,O	30	11/18/64	402	P
2-66-19ccdc	RMA	N	15	3/13/56	139	G
2-66-20addc	RMA #47	N,O	22	11/17/64	210	P
2-66-21cddc	RMA #54	N,O	30	11/18/64	142	P
2-66-31bdda	RMA #20	N,O	28	11/17/64	46	P
2-66-31dacd	RMA	--	41	10/3/55	43	G
2-66-32dcdd	RMA	--	49	10/3/55	50	G
2-67-1adbb	G. Squires	I	34	7/16/63	115	C
2-67-1bbbb	J. Salthouse	D	46	8/11/64	134	C
2-67-1bb	R. Weaver	--	44	6/24/63	112	C
2-67-1bdbb	G. Squires	I	40	7/16/63	123	C

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]/	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]/
2-67-2caca	R. Brakes	I	40	6/10/63	119	C
2-67-2cdd	C. Erger	I	40	7/9/63	94	C
2-67-3bdbd	J. Himes	S,I	32	8/12/64	112	C
2-67-3cccd	G. Furguson	I	11	1/23/62	506	R
2-67-3dbda	M&G Feedlot	S	60	4/23/63	145	C
2-67-3ddc	H. Penrod	I	--	7/30/63	306	C
2-67-4dbdc	RMA #55	N,O	30	11/18/64	68	P
2-67-5dddd	T. Abbott	--	--	2/10/64	125	C
2-67-9abac	RMA #57	N,O	29	1/30/62	81	R
2-67-9bdba	RMA #56	N,O	30	11/18/64	78	P
2-67-9ccdd	H. Thomas	--	10	1/23/62	78	R
2-67-9daac	E. Aden	I	30	8/12/64	625	C
2-67-10bddc	W. Myers	I	47	12/14/61	310	R
2-67-10addd	R. Humphreys	I	49	1/29/62	215	R
2-67-11aaba	J. Fry, Sr.	S	44	8/11/64	149	C
2-67-11baca	B. Murray	I	50	11/4/64	288	R
2-67-11bdad	B. Murray	I	60	8/11/64	310	C
2-67-11daaa	RMA #113	N,O	54	11/18/64	382	P
2-67-11dcaa	P. Erger	I	50	5/27/64	990	R
2-67-12cadb	RMA #112	N	50	8/18/61	191	R
2-67-12cbba	DM&H Cattle Company	S	45	1/22/62	399	R
2-67-12ccaa	T. Bollers	D	50	10/20/64	500	R
2-67-13abcb	RMA #111	N,O	46	8/18/61	435	R
2-67-13bddd	RMA #77	N,O	40	5/17/62	328	R
2-67-13cad	J. Stohr	N	41	12/14/60	380	R
2-67-14bddc	RMA #95	N,O	36	10/20/61	618	R
2-67-14cab	RMA #58	N,O	32	12/18/61	786	R
2-67-15abca	RMA #87	N,O	58	4/25/63	111	R
2-67-15bacc	RMA #89	N,O	40	4/25/63	379	R
2-67-15badd	RMA #88	N,O	43	1/17/63	347	R
2-67-15bcba	RMA #90	N,O	35	4/25/63	580	R
2-67-15dcbc	D. Heinz	I	42	7/30/63	347	C

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
2-67-16acda	RMA #92	N,O	40	4/25/63	138	R
2-67-16adac	RMA #91	N,O	32	4/25/63	360	R
2-67-16ccaa	P. Latorria	D	50	1/9/64	104	C
2-67-16cccc	D. Latorria	--	50	12/17/63	86	C
2-67-16dbbb	J. Priola	I	50	1/23/62	138	R
2-67-21addc	RMA #86	N,O	57	10/16/64	330	R
2-67-22abbb	RMA #82	N,O	40	11/12/64	165	R
2-67-22badb	RMA #83	N,O	44	11/12/64	1410	R
2-67-22bcda	RMA #85	N,O	45	11/12/64	1525	R
2-67-22bdbb	RMA #84	N,O	45	11/12/64	1016	R
2-67-22cadc	RMA #108	N,O	40	11/10/64	1850	R
2-67-22cdbc	RMA #104	N,O	55	6/5/62	2108	R
2-67-22cddd	RMA #43	N,O	27	11/10/64	2180	R
2-67-22dbad	RMA #1	N,O	40	11/10/64	1750	R
2-67-22ddba	RMA #2	N,O	49	6/5/62	1114	R
2-67-23addd	RMA #115	N,O	31	6/5/62	1999	R
2-67-23cdbb	RMA #71	N,O	63	6/5/62	1540	R
2-67-23cddc	RMA #72	N,O	61	11/10/64	400	R
2-67-23dbca	RMA #25	N,O	20	11/10/64	3075	R
2-67-24acac	RMA #78	N,O	30	12/7/60	112	R
2-67-24bbbb	RMA #60	N,O	--	6/30/64	960	R
2-67-25ddab	RMA #61	N,O	12	11/17/64	114	P
2-67-26abca	RMA #118	N,O	39	11/17/64	1550	P
2-67-26acab	RMA #73	N,O	61	6/14/62	1256	R
2-67-26baad	RMA #3A	N,O	39	11/17/64	766	P
2-67-26bbad	RMA #62	N,O	51	11/17/64	350	P
2-67-26bdcc	RMA #117	N,O	44	6/14/62	863	R
2-67-26cba	RMA #4	N,O	--	6/14/62	1648	R
2-67-26cbd	RMA #98	N,O	--	6/14/62	4205	R
2-67-27acbd	RMA #68	N,O	50	11/10/64	1780	R
2-67-27addc	RMA #67	N,O	44	4/29/64	1010	R
2-67-27bbbd	RMA #103	N,O	55	6/5/62	142	R
2-67-27bcad	RMA #99	N,O	72	11/10/64	850	R
2-67-27ddbd	RMA #100	N,O	50	6/14/62	1726	R

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
2-67-28aaaa	Irondale Trailer Ct.	D	51	11/12/64	106	P
2-67-28abb	A. Hessling	D,I	51	1/6/64	45	C
2-67-28daa	E. Ullaberri	--	50	11/17/59	42	C
3-66-9bbcc	Jeremiassen	I,S	32	10/7/55	71	G
3-66-17bdcd	B. Bollers	I	70	10/5/55	26	G
3-67-1dddd	RMA #10	N,O	77	11/17/64	49	P
3-67-2acbc	RMA #109	N,O	30	11/17/64	2020	P
3-67-5abcd	S. Adams WSD #2(S-7)	P.S.	80	11/12/64	123	P
3-67-5acd	D. Pfeif	--	65	8/6/63	105	C
3-67-5dddd	S. Adams WSD #2(S-5)	P.S.	80	11/12/64	92	P
3-67-5dddd	S. Adams WSD #3(S-6)	P.S.	80	11/12/64	103	P
3-67-6ccdc	S. Adams WSD #2(S-2)	P.S.	43	11/12/64	123	P
3-67-6ccdc	S. Adams WSD #3(S-3)	P.S.	45	11/12/64	141	P
3-67-7acaa	Town & Country #2	P.S.	22	11/24/64	142	P
3-67-7addd	Town & Country #1	P.S.	42	11/24/64	148	P
3-67-8abbc	--	--	70	4/9/63	126	C
3-67-8dccd	S. Adams WSD __(S-4)	N	80	4/63	106	C
3-67-13bbbb	F. Bostic	D	75	10/7/55	28	G
3-67-14acaa	B. Bollers	I	51	10/6/55	43	G
3-67-18bdda	Oriental Refining Co.	Ind,C	45	7/5/55	75	G
3-68-12cbab	Packaging Corp. of America	Ind	32	1/6/58	194	L

Appendix C (Continued)

Location (T-R-Sec.)	Owner	Use of Water[a]	Well Depth (ft)	Sampling Date	Chloride ppm	Analyst[b]
3-68-12cbbc	Litvak Packing Co.	Ind.	32	1/15/60	358	L
3-68-12cdca	Packaging Corp. of America	Ind.	21	6/30/58	125	L
3-68-12ccdb	Tenneco	Ind.	46	6/2/59	65	L
3-68-14abca	Denver Livestock Feeding Co.	S	18	6/26/59	270	L
3-68-14baac	Denver Livestock Feeding Co.	S	18	6/29/59	168	L

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[a]

C	Cooling	Ind	Industrial	S	Stock
D	Domestic	I	Irrigation	L.I.	Lawn Irrigation
P	Processing	O	Observation purposes	P.S.	Public Supply
				N	Not used

[b]

C	Colorado State Department of Public Health
G	U.S. Geological Survey
L	Private Laboratory Results Reported by U.S.G.S.
P	U.S. Public Health Service
R	U.S. Army, Rocky Mountain Arsenal
U	Colorado State University

[c] Composite Sample

M. A. Bauer

BARR LAKE AND ITS ODOR RELATIONSHIPS

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Water Supply and Pollution Control
Region VIII
Denver, Colorado

Robert O. Sylvester
University of Washington
Sanitary Engineer Consultant
and
South Platte River Basin Project
Denver, Colorado

December 1965

M. A. Bauer

SOUTH PLATTE RIVER BASIN PROJECT
U. S. PUBLIC HEALTH SERVICE

Background and Objectives

On July 18, 1963, the Governor of Colorado requested the Secretary of Health, Education, and Welfare to assist the State in determining sources of pollution and quality of waters of the South Platte River Basin within the State of Colorado.

The First Session of the Conference in the Matter of Pollution of the South Platte River Basin was held in Denver, Colorado, on October 29, 1963, under the provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 466g). It was established at this conference that a study would be undertaken by facilities of the U. S. Public Health Service. Findings and recommendations from this study would lead to a program of pollution abatement to be developed jointly by the South Platte River Basin Project, Public Health Service, and the Colorado State Department of Public Health.

The long-range goals and objectives of the Project are as follows:

1. Determine the legitimate water uses and locate the sources of pollution having an adverse effect on those uses.
2. Through field investigations determine the physical, chemical and biological responses of the river to pollution and evaluate the previously located sources of pollution with respect to the conditions in the river.
3. Compute the waste load reductions necessary to obtain desired water quality and recommend water quality control measures needed to effect the desired waste load reductions.

Organization

The South Platte River Basin Project consists of engineering and associated professional and clerical personnel. The Project headquarters offices are located in downtown Denver and the laboratory has been established at the Colorado State Department of Public Health, Denver, Colorado. The Project is administratively attached to the Water Supply and Pollution Control Program of the Public Health Service, United States Department of Health, Education, and Welfare, Region VIII, Denver, Colorado.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the following agencies and groups for the assistance and cooperation which made this report possible.

Colorado State Department of Public Health
Denver, Colorado

Colorado State Engineers Office
Denver, Colorado

Tri-County Health Department
Commerce City, Colorado

Farmers Reservoir and Irrigation Company
Denver, Colorado

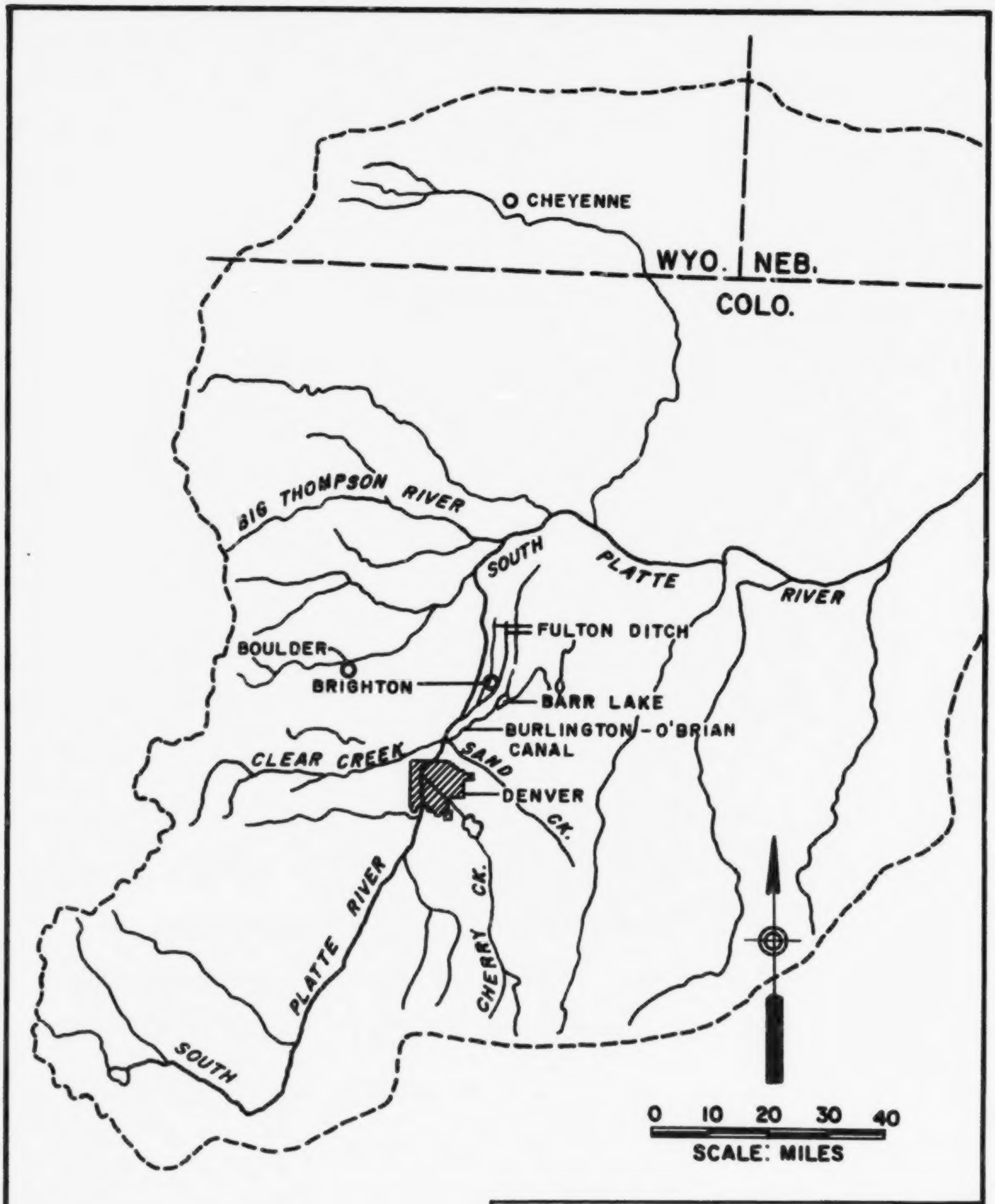
Barr Lake Hunting Club
Denver, Colorado

INTRODUCTION

The South Platte River and its tributaries in the vicinity of Denver, Colorado, are principal sources of water supply for the area. They are also the receptacle for used water. Water is used and reused for domestic and industrial water supply and for irrigation. Established water rights regulate the amount of withdrawal and period of withdrawal for the water in the River system. As the population of the area has grown over the years, the competition for this water has intensified along with the necessity for increased reuse. To help in meeting the need for water reuse, the City of Denver constructed a sewage treatment plant and placed it in operation in 1937 (1). Since then, other communities have constructed sewage treatment plants discharging to the South Platte River system. Additional domestic and industrial waste water treatment facilities are needed. There is also a need for the connection of numerous domestic and industrial discharges into the existing sewer systems.

Water is diverted from the South Platte River into the Burlington-O'Brian Canal immediately downstream from the Denver North Side sewage treatment plant as shown in Figure 1.

(Figure 1 is as follows:)


CHEYENNE
WYO.
NEB.
COLO.
BIG THOMPSON RIVER
SOUTH
PLATTE
RIVER
FULTON DITCH
BOULDER
BRIGHTON
BARR LAKE
BURLINGTON - O'BRIAN CANAL
CLEAR CREEK
SAND CK.
DENVER
CHERRY CK.
PLATTE RIVER
SOUTH
0 10 20 30 40
SCALE: MILES

SOUTH PLATTE RIVER BASIN PROJECT

UPPER SOUTH PLATTE
RIVER BASIN

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VIII
DENVER, COLO.

FIGURE-1

This canal is used by the Farmers Reservoir and Irrigation Company for storing irrigation water in Barr Lake through diversion of South Platte River water chiefly during the non-irrigation season. It is also used to supply the Denver-Hudson Canal and the Burlington Ditch. Water of similar quality is diverted by others from the South Platte River into the nearby Fulton Ditch and the Brantner Ditch.

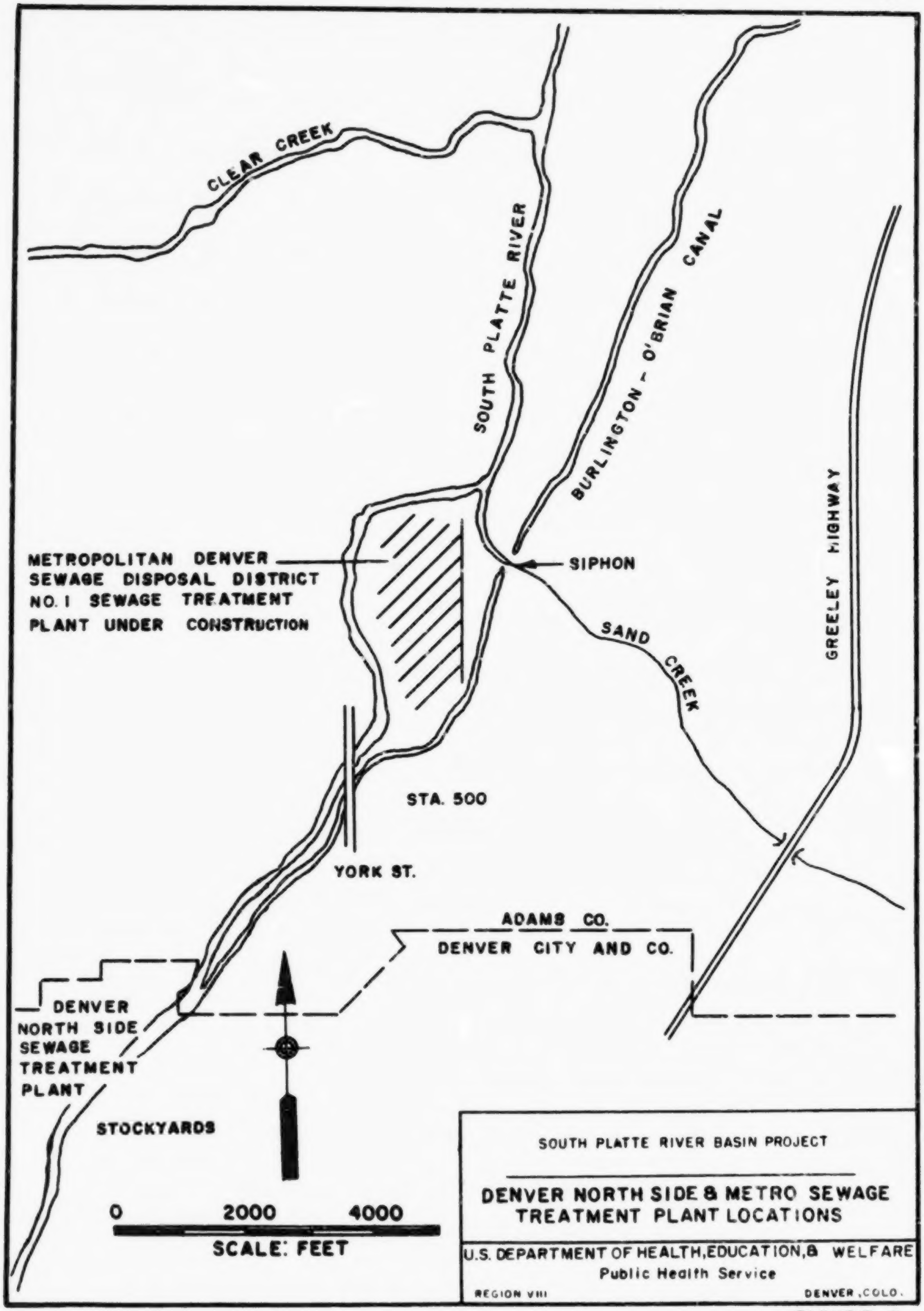
Over the years, numerous complaints of odors have been received from Brighton and vicinity (2), a city of some 10,000 persons, located about 2.7 miles northwest of Barr Lake. These odors have been attributed to Barr Lake (1) (2) (3) (4) (5) and the organic loading imposed on this lake through incomplete treatment of Denver's sewage.

Several studies have been made on this situation, including a Public Health Service investigation in 1948-50, a Colorado State Health Department report (1) in 1956, and the study of Professor Ross E. McKinney (3) in 1963. On October 29, 1963, the South Platte River Basin Project (2) was initiated following an Enforcement Conference held by the Department of Health, Education, and Welfare, Public Health Service, at the request of the Governor of Colorado under the provisions of the Federal Water Pollution Control

Act as amended (33 U.S.C. 466g). During 1964, Brighton (2) began formal action against several municipalities for their alleged pollution of the South Platte River in the vicinity of Denver. This action was dismissed in court on the grounds that Denver was making satisfactory progress to correct the situation through formation of a sewage disposal district.

During the period of 1960-63, the Metropolitan Denver Sewage Disposal District No. 1 was formed to cope with the sewerage problems of the area. This District commenced construction of secondary sewage treatment facilities in August of 1964, locating the new plant (Figure 2) downstream of the Burlington-O'Brian Canal.

(Figure 2 is as follows:)


CLEAR CREEK
SOUTH PLATTE RIVER
BURLINGTON - O'BRIAN CANAL
GREELEY HIGHWAY
METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 SEWAGE TREATMENT PLANT UNDER CONSTRUCTION
SIPHON
SAND CREEK
STA. 500
YORK ST.
ADAMS CO.
DENVER CITY AND CO.
DENVER NORTH SIDE SEWAGE TREATMENT PLANT
STOCKYARDS
0
2000
4000
SCALE: FEET

SOUTH PLATTE RIVER BASIN PROJECT

DENVER NORTH SIDE & METRO SEWAGE TREATMENT PLANT LOCATIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VIII DENVER, COLO.

FIGURE-2

Effluent is to be pumped back to the canal as necessary to meet "water right" flow agreements. These additional treatment facilities are not expected to have any immediate influence on the existing South Platte River water quality above the point of effluent discharge from the Denver North Side treatment plant. Numerous domestic and industrial waste discharges must be connected into existing sewer systems.

This study was based on data developed by the South Platte River Basin Project and others as referenced. The purpose of this study was to:

1. Evaluate the present conditions in Barr Lake.
2. Determine the probable conditions to be expected in Barr Lake after completion of the new Metropolitan Denver Sewage Disposal District No. 1 treatment facilities and the approximate length of time required for the lake to reach these conditions.
3. Recommend measures that might be used for correcting the probable future water quality conditions in Barr Lake should the conditions continue unfavorable after completion of MDSDD#1 treatment facilities.
4. Recommend measures that might be used for

improving Barr Lake water quality prior to completion of the MDSDD#1 facility.

BASIC DATA

Characteristics of the study area, the South Platte River, Burlington-O'Brian Canal, Barr Lake, and the sewage treatment facilities are presented in the following pages. Since river flows, temperatures, etc., vary so widely from year to year, monthly means for the past ten years are included in the data for comparative purposes. Water quality data obtained by the South Platte River Basin Project are presented and discussed in a later chapter of this report.

Climatological

Table I lists the yearly normal and study period precipitation and temperatures by the month at the Denver Airport. Also shown is the mean 1961-64 evaporation at Wiggins. The normal annual precipitation is 14.81 inches with about 70 percent of this occurring in the spring and summer. April, May, October and November have relatively warm days and cold evenings. The average evaporation, as measured in the non-freezing period from April to October of 1961-64, was 56.4 inches. Actual evaporation, of course, exceeds this by several inches due to sublimation of ice and snow and from liquid surfaces during portions of March and November. The study period from March of 1964 to March of 1965 was drier than normal, although temperatures were about normal.

The United States Weather Bureau has recorded a mean yearly wind direction in the Denver-Brighton area as shown below, during the period of 1931 to 1960, having a mean monthly velocity of 8-11 mph.

South	30%	North	8%
Southwest	20%	East	8%
Southeast	10%	Northwest	7%
Northeast	10%	West	7%

This prevailing southerly wind usually develops in the area after dark unless the local weather is being dominated by a particular storm system. The mean monthly wind velocities during the study period were as shown below. Wind directions followed the pattern above.

March 1964	8.8 mph
April 1964	9.5 mph
May 1964	8.6 mph
June 1964	7.8 mph

M. A. Bauer

July 1964	7.0 mph
August 1964	8.8 mph
September 1964	7.6 mph
October 1964	7.1 mph
November 1964	8.2 mph
December 1964	9.2 mph
January 1965	9.0 mph
February 1965	8.7 mph
March 1965	7.3 mph
April 1965	9.5 mph

(Table I is as follows:)

TABLE I

Climatological Data[1]

Month	Mean Annual[2] Precip. In.	Mean Annual[2] Temp. °F	1963 Mean Precip. In.	1963 Mean Temp. °F	1964 Mean Precip. In.	1964 Mean Temp. °F	1965 Mean Precip. In.	1965 Mean Temp. °F	Evaporation Inches
January	0.55	28.5	0.71	19.1	0.26	30.6	1.00	35.0	-
February	0.69	31.5	0.21	37.3	1.04	27.4	1.27	27.4	-
March	1.21	36.4	1.42	37.3	1.38	33.0	1.20	29.0	-
April	2.11	46.4	0.03	50.0	1.25	46.6			7.6
May	2.70	56.2	0.68	60.9	2.53	58.8			9.6
June	1.44	66.5	3.59	66.7	0.82	65.0			9.5
July	1.53	72.9	0.55	74.8	0.72	75.8			11.1
August	1.28	71.5	2.52	68.7	0.27	70.4			7.9
September	1.13	63.0	1.25	65.9	0.41	62.5			6.1
October	1.01	51.4	0.31	57.9	0.18	52.7			4.6
November	0.69	37.7	0.45	41.7	0.88	40.0			-
December	0.47	31.6	0.51	28.5	0.40	33.2			-
	14.81	49.5	12.23	50.8	10.14	49.7			56.4

[1] U.S. Weather Bureau, Denver Airport, except evaporation which is the 1961-64 mean for Wiggins, Colorado.

[2] Period of record, 30 years to 1964.

M. A. Bauer

Flow Data, South Platte River

In Table II is given the 10-year mean monthly discharge of the South Platte River above the Denver North Side sewage treatment plant; the sewage treatment plant discharge; the diversion into the Burlington-O'Brian Canal; the percent of river flow diverted into the Burlington-O'Brian Canal; and the percent of river flow that consists of Denver sewage plant effluent.

(Table II is as follows:)

TABLE II

Discharge and Diversion Data; 10-Year Mean; Cubic Feet per Second (CFS)

Month	South Platte River Above Denver STP[1]	Denver STP[2]	Percent Flow from Denver STP	Burlington-O'Brian Canal Diversion[3]	Percent River Flow Diverted
January	70	95	58	137	83
February	84	81	49	106	65
March	140	89	39	127	55
April	265	87	25	135	38
May	635	96	13	129	18
June	432	84	16	170	33
July	304	103	25	85	21
August	325	104	24	73	17
September	157	98	38	67	26
October	131	97	43	118	52
November	128	90	41	156	71
December	93	91	49	151	82
		93			47

---

[1] U.S.G.S. data; Oct. 1953 - Sept. 1963; 19th St. Bridge

[2] Denver North Side Sewage Treatment Plant Records, 1954-63

[3] Burlington Ditch Reservoir and Land Co. Records, Jan. 1954 - Dec. 1963

River flow is normally greatest in the period of April through August. The sewage treatment plant discharge has averaged about 93 cfs (60mgd) during the past 10 years, but has now increased to a present mean of about 110 cfs. Below the point of Denver's treatment plant discharge, the percent of flow in the river representing the Denver North Side treatment plant effluent has ranged from a high of 58 percent in January to a low of 13 percent in May. This effluent has averaged 35 percent of the river flow for the entire year, which is a significant percentage. Because of upstream effluent discharges, the percent of used water in the South Platte River is considerably higher than indicated on Table II. The quantity of water diverted into the Burlington-O'Brian Canal for Barr Lake storage is greatest in the non-irrigation months of October-March. Diversion in the other months is usually for direct application. The largest percentage of river flow is also diverted in the non-irrigation months of October through March, a period when the normal river flow is the least. This has averaged over 80 percent in December and January.

Table III lists the actual monthly flow values during the period of study. During this period, South

Platte River flows were significantly less than the 10-year norm (Table II) in every month.

(Table III is as follows:)

TABLE III

Mean Monthly Flow Data for Study Period
(Values in CFS)

Month	South[1] Platte River	Denver North Side STP	Burlington-O'Brian Canal Diversion	Percent South Platte R. Flow Diverted	Barr Lake Inlet	Barr Lake Outlet	Barr Lake Contents AC-FT	Barr Lake Surface Area Acres
Mar. 1964	90	102	187	97	77	0	21,770	1550
Apr.	177	103	271	97	143	10	28,358	1790
May	314	100	49	12	4	119	19,172	1450
June	188	102	110	38	22	17	18,397	1400
July	169	129	34	11	0	155	6,279	720
Aug.	235	122	28	8	0	71	857	315
Sept.	60	101	27	17	0	7	0	0
Oct.	41	117	35	22	8	5	320	245
Nov.	70	112	89	49	18	0	730	300
Dec.	51	109	150	94	125	0	7,869	825
Jan. 1965	51	104	104	67	74	0	12,208	1090
Feb.	54	99	34	22	0	0	11,504	1065
Mar.	70	122	73	38	31	0	12,958	1135
		109		44				

[1] Above Denver North Side Sewage Treatment Plant

Burlington-O'Brian Canal

The South Platte River is diverted into the Burlington-O'Brian Canal about one-quarter mile below the Denver North Side sewage treatment plant outfall at the north Denver City and County limits (see Figure 2). In some years when River flow is down, water is not diverted during a portion of the spring and summer. A decree was granted the Farmers Reservoir and Irrigation Co. in 1957 permitting them to divert additional water providing it was put to direct use and not stored in Barr Lake. Diversion for Barr Lake storage is normally during the non-irrigation months.

The canal is 17.2 miles long to Barr Lake and has a flow time that is estimated to vary between 12 and 17 hours, depending upon the rate of flow. In addition to supplying water for Barr Lake, the Canal carries water for the Denver-Hudson Canal and the Burlington Ditch. The water in Burlington Ditch is distributed for direct use while that in the Denver-Hudson Canal is used to fill other irrigation storage reservoirs north and east of Brighton as well as for direct use.

Canal diversions from the South Platte River during the study period were greater than the 10-year norm in the months of March and April, the same in December, and less in the other months.

M. A. Bauer

Barr Lake

Barr Lake is essentially an artificial impoundment that is filled by diversion from the South Platte River principally during the non-irrigation season. It normally discharges during the period of May through September into the Speer Canal, east and west Burlington Extension Ditches, Beebe Seep Canal, and Neres Canal. Barr Lake is located about 2.7 miles southeast of Brighton and 14 miles northeast of Denver.

Physical characteristics of the Lake are:

1. Volume, full pool, 33,011 acre-feet: 32,152 acre-feet usable.
2. Surface area, full pool: 1870 acres, or 2.92 square miles.
3. Full pool elevation, 5094 feet.
4. Dead pool elevation, 5060 feet.
5. Maximum depth, full pool, 42 feet.

Table IV shows the average inflow and outflow from Barr Lake during the past 10 years.

(Table IV is as follows:)

TABLE IV

Barr Lake Water Budget Data[1] Mean Monthly Values
Nov. 1953 to End Oct. 1963

Month	Inflow		Outflow		Reservoir			
	AC-FT	CFS	AC-FT	CFS	Contents AC-FT[2]	Surface Elev.	Area Acres	Mean Depth[7]
Jan.	4574	77	-	-	17,506	5085	1350	13
Feb.	3471	58	-	-	20,092	5086.5	1445	14
Mar.	2589	43	-	-	21,709	5088	1552	14
Apr.	3242[4]	54[4]	513[5]	8[5]	23,380	5089	1616	14.5
May	3266[4]	55	4359	69	20,879	5087	1478	14
June	3641[4]	61[4]	5271	89	17,901	5085	1350	13
July	985[3]	17[3]	6069	102	11,026	5079.5	1030	11
Aug.	848[6]	14[6]	5394	90	5,061	5072.5	645	8
Sept.	1035[5]	17[5]	1934	33	3,614	5070	550	7
Oct.	3182[4]	53[4]	424[4]	7[4]	6,119	5074	717	9
Nov.	4186[4]	70[4]	14[3]	-	9,831	5078.5	960	10
Dec.	4518	76	-	-	13,547	5082	1156	12

[1] Calculated from Irrigation Co. data obtained by PHS

[2] Last day of month

[3] One year of flow only

[4] No flow in some years

[5] Three years of flow only

[6] Five years of flow only

[7] Volume divided by surface area. Reservoir has been completely emptied by Sept., Oct., or Nov. three times in past 10 years.

In an average year, the Lake is not filled prior to the irrigation season nor is it empty at the end of the irrigation season. In 1964 it was empty before the end of the irrigation season. In March of 1965, the Lake contained only 60 percent of its normal volume. The mean yearly total inflow has been 35,537 ac-ft. while the outflow (Table IV) has been 23,978 ac-ft. As the mean evaporation would total about 6,000 ac-ft., it is evident that seepage losses from the Lake are significant.

Existing Denver North Side Sewage Treatment Plant

The existing Denver North Side sewage treatment plant was placed in operation in 1937 to serve a population of about 240,000 persons together with industrial effluent (1). Chemical coagulation, sedimentation, filtration through magnetite filters, and separate sludge digestion were provided in the original construction. Shortly after the plant went into operation, the chemical coagulation and magnetite filter processes were discontinued because of cost and operating problems. In later years, pre-aeration and additional facilities for conventional primary treatment (plain sedimentation) were added. The effluent is intermittently chlorinated and passes through a chlorine contact tank. Sludge digestion and hydraulic capacities are overloaded at times resulting in sludge discharge to the River and by-passing of the treatment plant.

It is estimated that the present total population equivalent (on a biochemical oxygen demand basis) connected to the treatment plant is 1,020,000 persons. (SPRB Project estimate based on average BOD values.)

Metropolitan Denver Sewage Disposal District No. 1 Plant

In August of 1964, MDSDD #1 commenced construction on secondary (biological) sewage treatment facilities that are scheduled to be completed in late 1966 or early 1967. The new plant is located about one and one-half miles downstream from the existing Denver North Side plant and thus will be below the Burlington-O'Brian Canal diversion point. In February of 1965 two irrigation companies and an irrigation district filed a $25 million civil suit (5) in the District Court at Brighton, charging that the new sewage treatment plant being built in Adams County by the Metropolitan Denver Sewage Disposal District will deprive Adams and Weld County farmers of at least 50,000 acre-feet of irrigation water annually. It is anticipated that plant effluent will be pumped back into the Canal as necessary to satisfy existing water rights.

The MDSDD #1 plant will provide activated sludge treatment by either the step or conventional aeration processes, involving a detention period of about four hours at the design average flow of 117 MGD, allowing for 25 percent return sludge. The Denver North Side primary treatment plant will continue to operate and its effluent will be pumped to the new plant and metered directly into the aeration units. Raw sewage from the Sand and Clear Creek drainage basins will pass through screens and a grit and grease removal unit of the aerated type, prior to entering the new primary sedimentation basins. Activated sludge aeration basin effluent will pass through secondary settling basins and then a chlorine contact chamber. From the chlorine contact chamber, the plant effluent will pass into the South Platte River or be pumped as necessitated by water right agreements to the Burlington-O'Brian Canal.

Digested sludge from the Denver North Side plant will be pumped to the Metro plant for disposal with Metro sludge. Metro primary sedimentation sludge is to be combined with the waste activated sludge (concentrated by air flotation) for chemical coagulation and dewatering on vacuum filters. Incineration or flash drying will be used for the final disposal of all sludges.

The consulting engineer's design criteria (6) do not indicate how much plant capacity is reserved for future organic load increases.

(Figure 3 is as follows:)

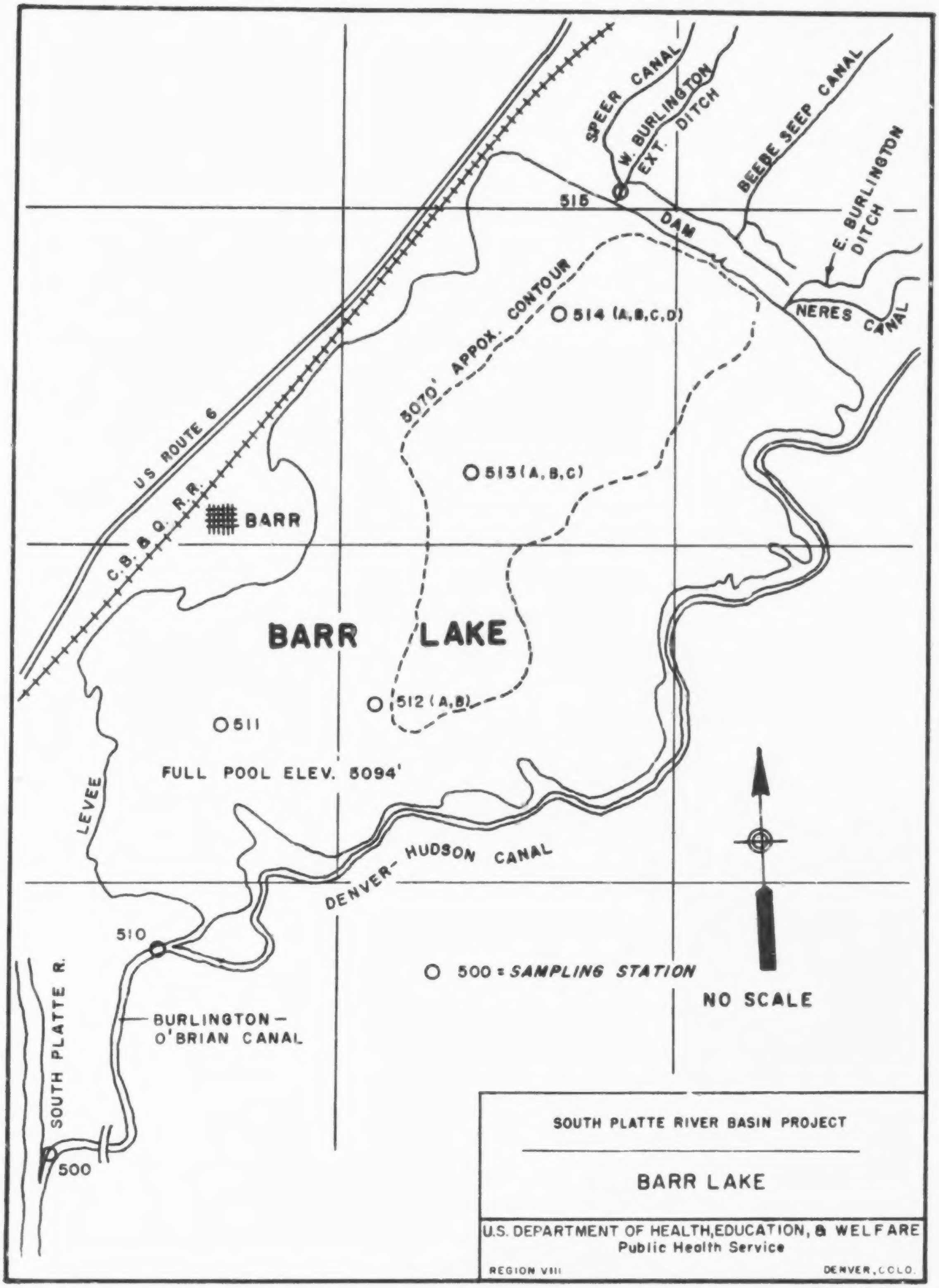

SPEER CANAL
W. BURLINGTON EXT. DITCH
BEEBE SEEP CANAL
E. BURLINGTON DITCH
515
DAM
NERES CANAL
US ROUTE 6
C.B. & Q. R.R.
BARR
3070' APPOX. CONTOUR
514 (A,B,C,D)
513 (A,B,C)
BARR LAKE
512 (A,B)
511
FULL POOL ELEV. 5094'
LEVEE
DENVER-HUDSON CANAL
510
SOUTH PLATTE R.
BURLINGTON-O'BRIAN CANAL
500
500 = SAMPLING STATION
NO SCALE
SOUTH PLATTE RIVER BASIN PROJECT
BARR LAKE
U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VIII
DENVER, COLO.

FIGURE-3

THE PROBLEM

The South Platte River is polluted by municipal and industrial wastes in the vicinity of Denver and pollution is particularly severe during periods of low stream flow. A major portion of this pollution originates at the Denver North Side sewage treatment plant which provides only primary sewage treatment and has facilities which are frequently overloaded. An attempt by Adams County to force the Colorado Health Department to take court action against five metropolitan communities for polluting the South Platte River was rejected in a Denver district court on June 3, 1965 (5).

There are essentially three problems; one is the present polluted condition of the South Platte River; another is the use of this River water for irrigation and stock watering; and the other is the presence of disagreeable seasonal odors which have been attributed to Barr Lake and its contents of South Platte River water. This study is concerned only with an analysis of the odor problem.

Until the Public Health Service started the South Platte River Basin Project water quality studies in March of 1964, there had been only random[1] samplings of the treatment plant effluent, the River and the Lake. The odor problems in Brighton have been blamed on Barr Lake (5) with little substantiating or documentary evidence that they all or partially originated in Barr Lake, other than some limited observations by Mr. R. E. Sandersfeld, the former Brighton City Engineer (4).

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[1] By other than the City of Denver

Barr Lake Odors

Odors observed in Brighton may originate from a number of possible sources, including Barr Lake. These would include the Gates-Cyclo poultry waste lagoon, a number of feed lots, several industries, the Burlington, the Fulton and the Brantner ditches, and the Skeel Reservoirs. Odors emanating from the ditches or reservoirs would be caused by the same source as odors from Barr Lake.

The prevailing wind direction is from the south and southwest as measured by the Weather Bureau at Stapleton Field. This would place Brighton somewhat downwind from Barr Lake.

Mr. Sandersfeld, former City Engineer of Brighton describes[1] (4) the odors attributed to Barr Lake as resembling that of hydrogen sulfide. He stated that they were quite noticeable in the months of March to late May and from late October to late November, beginning quite consistently about 7:00 pm and ending about 11:00 pm. This, as suggested by Mr. Sandersfeld, can be due to a temperature inversion in the evening. The days are sunny and reasonably warm, creating a rapid temperature lapse with distance above the ground. This condition would permit any odors from Barr Lake to rise and be widely dissipated. After or near sundown, the ground temperature drops rapidly while the air still remains relatively warm, creating a temperature inversion near the ground. This prevents any odors from rising and dissipating through dilution. A southerly wind could then carry the concentrated odors a considerable distance before they would become diluted and undetected. The temperature inversion would be dispelled later in the evening through natural cooling of the air.

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[1] Mr. Sandersfeld made these observations from the autumn of 1962 into the spring of 1964. Odors were not reported in the autumn of 1964 but were observed near the Lake in the spring of 1965. As shown in Tables III and V, the organic loading imposed on Barr Lake in October and November of 1964 was relatively small.

The South Platte River contains a relatively large amount (compared to most other U. S. rivers) of sulfates. These sulfates are reduced to other compounds such as sulfides, which are odorous, under prolonged anaerobic conditions. Barr Lake is probably in an anaerobic state during the winter and a portion of the spring and autumn of each year under present conditions. The greater the sulfate content of the water, the more sulfur there is available for odorous compounds.

PRESENT CONDITION OF BARR LAKE

As discussed in a previous section, Barr Lake is supplied with water from the South Platte River through the Burlington-O'Brian Canal. There is an inadequacy of data on which to base a rigorous calculation of the organic pollution load imposed on Barr Lake. Data do exist however for generalized observations on probable mean conditions. A plot of South Platte River flow rates with the limited available observations on River BOD values both above and below the Denver North Side Sewage Treatment Plant does not show good correlation between flow rates and BOD values. Factors other than dilution are involved in the River BOD above the treatment plant; factors such as seasonal industrial activity, flushing of storm sewers, and sewer overflows. A study of River BOD data available indicates that a mean yearly value of 15 mg/l (5-day, 20° C) would be a reasonable one to use for approximate calculations.

Adequate flow data on the River and the Denver North Side plant effluent are available as well as on the plant effluent BOD.

Biochemical Oxygen Demand Loading

Table V gives the estimated probable biochemical oxygen demand loadings on Barr Lake during the study period. BOD values in the Burlington-O'Brian Canal were calculated using mean monthly River and Denver North Side treatment plan flow values (Table III) together with an upstream River BOD value approximated at 15 mg/l as discussed in the previous section. These values tend to be low, or conservative, when compared with some of the BOD values that have been collected. They are intended to represent mean and not extreme conditions. Table V shows that the maximum BOD loadings occurred in the months of October to March when the Lake was least able to assimilate the organic loading. No BOD reduction was assumed in the Canal because the reduction is small and because of the intermittent discharge of sludge into the River that is not reflected in treatment plant effluent BOD values. The possible significance of the BOD loadings on Barr Lake is discussed in a later portion of this section.

(Tables V and VI, are as follows:)

TABLE V

Biochemical Oxygen Demand[1] Loadings on Barr Lake
(Estimated Mean Monthly in Study Period)

Month	Mean S. Platte River Flow CFS[2]	Mean Denver North Side STP Flow CFS[3]	Mean Denver North Side STP BOD mg/l[3]	Combined BOD in River Below STP mg/l[4]	Barr Lake Inflow CFS[5]	BOD Loading Barr Lake Thous lbs /Day	BOD Loading Barr Lake lbs/Acre/ Day
Mar. 1964	90	102	119	70	77	29	18.7
Apr.	177	103	175	73	143	56	31.4
May	314	100	173	53	4	1.1	0.8
June	188	102	155	64	22	7.6	5.4
July	169	129	154	75	0	0	0
Aug.	235	122	139	58	0	0	0
Sept.	60	101	173	115	0	0	0
Oct.	41	117	184	140	8	6	24.6
Nov.	70	112	165	107	18	10	34.5
Dec.	51	109	179	127	125	85	103.0
Jan. 1965	51	104	174	122	74	48	44.3
Feb.	54	99	163	111	0	0	0
Mar.	70	122	198	131	31	22	19.2

[1] 5-day 20°C values

[2] Gaged flow above Denver North Side Sewage Treatment Plant

[3] From Denver North Side STP records

[4] Using a mean BOD in the South Platte River estimated at 15 mg/l

[5] From Table III

TABLE VI

Biochemical Oxygen Demand Loading on Barr Lake (Estimated Mean Monthly in Period 1953-1963)

Month	South Platte R. Above Denver STP[1] CFS	Denver STP[1] CFS	Combined BOD in River Below STP[2] mg/l	Barr Lake Inflow CFS[3]	BOD Loading Barr Lake Thous lbs /Day	BOD Loading Barr Lake lbs/Acre/ Day
Jan.	70	95	107	77	44.4	32.8
Feb.	84	81	94	58	29.3	20.3
Mar.	140	89	78	43	18.0	11.6
Apr.	265	87	55	54	16.0	9.9
May	635	96	36	55	10.6	7.2
June	432	84	41	61	13.5	10.0
July	304	103	55	17	5.0	4.9
Aug.	325	104	54	14	4.1	6.4
Sept.	157	98	77	17	7.0	12.7
Oct.	131	97	84	53	23.8	33.3
Nov.	128	90	81	70	30.5	31.8
Dec.	93	91	94	76	38.4	33.2

[1] Data from Table II

[2] Using River BOD of 15 mg/l and STP effluent of 175 mg/l

[3] From Table IV

Table VI for comparison gives the estimated probable BOD loadings on Barr Lake during the 10-year period represented in Table II. River BOD values above the treatment plant were taken at 15 mg/l as before and treatment plant effluent BOD values averaging 175 mg/l as reported in references (1) (2) and (3). Table VI indicates that the BOD loadings on Barr Lake during the study period (Table V) were alternately relatively light and heavy compared with the means of Table VI. During the study period (March 1964 to March 1965) there was no loading in the summer and heavier than usual loadings in the spring and winter, although none in February of 1965.

Table VI indicates that maximum BOD loadings occur in the colder months when the Lake is least able to assimilate them.

Water Quality Data

In March 1964, the South Platte River Basin Project established 13 sampling stations on Barr Lake and adjacent canals, as shown in Figure 3. The stations were sampled at about bi-weekly intervals at all locations except when Lake drawdown, cessation of irrigation flow, or freezing precluded their sampling. Sampling points were selected to show the quality of water diverted to Barr Lake; quality changes that may take place in the diversion canal; change in Lake quality with depth and with position in the Lake; change in quality after passing through the Lake or by traveling an equivalent distance in the Denver-Hudson by-pass canal. Sludge deposits in the Burlington-O'Brian Canal and in the Lake were investigated and sampled. Table VII lists the sampling station locations. Determinations were generally by standard procedures (7).

(Table VII is as follows:)

TABLE VII

Sampling Station Locations (See Figure 3)

Station No.	Location
500	Burlington-O'Brian Canal at York St. Bridge
510	Barr Lake Inlet at Denver-Hudson Canal diversion
511	Barr Lake, 1/4 point, 1-ft. depth
512A	Barr Lake, 1/2 point, 1-ft. depth
512B	Barr Lake, 1/2 point, 5-10 ft. depth
513A	Barr Lake, 3/4 point, 1-ft. depth
513B	Barr Lake, 3/4 point, 10-ft. depth
513C	Barr Lake, 3/4 point, 20-ft. depth
514A	Barr Lake, 4/4 point, 1-ft. depth
514B	Barr Lake, 4/4 point, 10-ft. depth
514C	Barr Lake, 4/4 point, 20-ft. depth
514D	Barr Lake, 4/4 point, 30-ft. depth
515	Outlet canal for Barr Lake

Tables VIII-XIV present the water quality sampling data at various depths for the sampling period and Table XV shows the mean values of bottom sludge analyses. Data presented in Tables VIII-XV were compiled from field and laboratory observations made by the South Platte River Basin Project, between the period of March, 1964 and May, 1965 (8). Data were not collected routinely because there was no Lake inflow in July, August, September and February; the Lake was empty in August; and the Lake was ice-covered from December to the middle of April, 1965. Water was not diverted into Barr Lake during most of April and May of 1965 because of low-water conditions in the South Platte River and because sewage from the Denver North Side STP was bypassed directly to the River from April 16 to June 3, 1965 to permit construction of plant modifications relative to the new Metro plant. A discussion of this water quality data follows:

General: Nitrate nitrogen, total nitrogen, total phosphate, and soluble phosphate concentrations were determined in samples collected after August of 1964. Data that are missing in the tables either were not collected or the analytical results were not reliable and therefore not reported. The few nitrogen and phosphate samples collected on the Canal and Lake on the same sampling trip indicated a complete reduction of nitrates in the Lake (anaerobic conditions persisted at the time), little change in organic nitrogen, and a phosphate reduction in the Lake of about 75 percent.

The BOD and COD values obtained did not present a uniform relationship other than that COD values were usually two to four times greater than the BOD values. This would be expected however.

Values obtained were from grab samples and thus individual results must be examined collectively since the water being sampled was constantly varying in quality due to changes in flow, treatment plant operations, and variations in the activity of the biota with diurnal changes in temperature and insolation. Samples were collected between 8:30 am and 7:30 pm, most samples being collected prior to 2:00 pm. The time of day that surface samples are collected from Barr Lake would have a large influence on the presence or absence of dissolved oxygen and the quantity of oxygen obtained, once photosynthesis has been established to a significant degree in the late spring.

(Table VIII is as follows:)

TABLE VIII

Burlington-O'Brian Canal at York Street Water Quality
Station 500

Constituent	1964							1965		
	3-19	3-26	4-9	4-23	6-4	12-2	12-22[1]	1-12[2]	3-29	4-6
Temp., °C	8.0	10.5	12.0	14.5	19.5	13.0	12.0	11.9	11.0	14.0
D.O., mg/l	6.9	6.6	4.8	4.4	4.8	3.1	3.7	3.0	4.6	4.2
pH	8.2	7.4	8.0	7.6	7.7	7.4	7.3	7.3	7.0	7.6
Tot. alk. as $CaCO_3$	190	200	225	165	210	-	-	-	-	-
BOD, mg/l	220	55	165	95	80	80	125	250	60	120
COD, mg/l	480	200	300	145	220	160	195	195	-	-
Cond. umhos/cm.	795	1260	1240	830	890	1120	990	1120	1010	1100
Chlorides, mg/l	104	160	132	74	81	101	111	96	120	117
Tot. Diss. Sol., mg/l	490	780	710	515	515	-	-	-	-	-
Susp. Sol., mg/l	2500	88	180	1590	1040	115	125	120	100	125
Vol. Susp. Sol., mg/l	330	50	140	640	650	80	105	110	50	90
Sett. Sol., mg/l	25	0.4	0.7	0.3	0.2	0.1	0.1	0.2	0.2	0.5
NO_3N, mg/l	0.20	0.44	0.52	0.66	0.26	0.38	0.28	0.21	0.74	-
Total N, mg/l	-	-	-	-	-	30	16.1	18.4	10.5	17.1
Total PO_4, mg/l	-	-	-	-	-	9.5	9.15	16.8	9.2	11.2
Sol. PO_4, mg/l	-	-	-	-	-	6.3	7.55	16.3	8.0	9.3
ABS, mg/l	0.3	1.4	2.4	2.3	0.9	0.7	-	-	-	-
Coliform/100 ml.	90,000	300	1,800	12,000	54,000	4,900	570,000	29,000,000	490	-

[1] Mean of samples on 12/15, 12/22 and 12/29

[2] Mean of samples on 1/6, 1/12 and 1/18

Burlington-O'Brian Canal, Station 500, Table VIII:

During the period sampled, the Burlington-O'Brian Canal at York Street (just after diversion from the South Platte River) had a variable quality depending upon the rate of river flow for effluent dilution and upon the presence of digester sludge and supernatant in the river (very high suspended solids were observed on several occasions). In general, Table VIII indicates the following:

1. Dissolved oxygen in appreciable amounts was present in the water diverted into the canal at all times of sampling.
2. The diverted water, considering that it came from a surface stream of mountain origin, was high in dissolved solids, alkalinity, and conductivity, indicating the presence of irrigation return flow and ground water seepage.
3. The diverted water had an extremely high (for a river water) biochemical oxygen demand, chemical oxygen demand, and volatile suspended solids content, indicating the presence of a large amount of inadequately or improperly treated sewage. BOD values averaged about 125 mg/1.

4. Coliform bacteria concentrations were relatively low when effluent disinfection was practiced and high when not. They were normally unusually high for any stream in an urban area.
5. Plant nutrients, in abnormally large amounts for a surface stream, were being diverted into Barr Lake.
6. pH values were normal but the content of synthetic detergents expressed as ABS was very High for a surface water.

(Table IX is as follows:)

TABLE IX

Barr Lake Inlet Water Quality
Station 510

	1964							1965		
Constituent	3-19	3-26	4-9	4-23	6-4	12-2	12-22[1]	1-12[2]	3-29	4-6
Temp., °C	9.0	8.5	13.5	15.0	17.3	9.5	12.1	9.3	10.0	12.0
D.O., mg/1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pH	7.4	7.4	7.5	7.6	7.4	7.3	7.3	7.4	7.4	7.5
Tot. alk. as $CaCO_3$	210	200	215	185	190	-	-	-	-	-
BOD, mg/1	130	115	125	90	55	150	135	135	96	120
COD, mg/1	335	265	260	215	85	200	225	200	-	-
Cond., umhos/cm	895	1420	1050	970	925	1250	1200	1090	965	1010
Chlorides, mg/1	106	206	156	111	84	-	133	108	123	100
Tot.Diss.Sol.,mg/1	575	820	830	625	510	-	-			
Susp. Sol., mg/1	555	230	1390	1140	290	122	170	155	260	125
Vol.Susp.Sol.,mg/1	135	135	920	610	240	79	120	110	120	75
Sett. Sol., ml/1	3.5	1.0	1.2	0.1	0.1-	0.4	0.5	0.4	-	-
NO_3N, mg/1	0.19	0.12	0.12	0.07	0.16	0.18	0.15	0.15	0.09	-
Total N, mg/1	-	-	-	-	-	36.8	15.3	18.0	13.8	12.4
Total PO_4, mg/1	-	-	-	-	-	10.6	16.1	21.2	12.6	16.0
Sol. PO_4, mg/1	-	-	-	-	-	1.1	9.6	17.8	10.0	12.8
ABS, mg/1	2.1	1.8	3.0	2.4	0.8	-	-	-	-	-
Coliform/100 ml.	790,000	1,300,000	49,000	1,300,000	3,500,000	-	6,000,000	7,200,000	28,000	-

[1] Mean of samples on 12/8, 12/15, 12/22 and 12/29

[2] Mean of samples on 1/6, 1/12 and 1/18

Barr Lake Inlet, Station 510, Table IX: During the 17 miles of flow in the canal to Barr Lake, the following water quality changes occurred:

1. The dissolved oxygen was found to be entirely consumed in all samples taken.
2. The pH was usually somewhat depressed due to the formation of amino acids and carbonic acid.
3. Some of the suspended solids were deposited on the canal bottom but this is not reflected in the sample values.
4. An aftergrowth of coliform bacteria was frequently observed, Barr Lake Inlet concentrations exceeding those at York Street.
5. Most of the nitrates were reduced to nitrites or ammonia.
6. A slight decrease in the mean BOD from 125 to 115 mg/1.

Other constituent values were not changed appreciably over those found in the water as diverted.

(Tables X through XIII are as follows:)

TABLE X

Barr Lake Surface Water Quality
Mean of Stations 511-514

Constituent	1964										1965	
	3-26	4-23	5-11	5-20[1]	6-4	6-18	7-1	7-16	8-6[3]	8-27[4]	4-30	5-6
Temp., °C	4.7	13.3	13.3	25.0	16.9	20.5	22.2	27.3	24.5	16.0	16.9	15.0
D.O., mg/1	0.0	0.0	0.0	7.9	0.6	13.0	1.4	2.4	3.6	10.2	0.0	0.0
pH	7.7	7.9	7.7	8.3	7.9	8.7	8.1	8.2	8.2	9.0	7.7	7.9
Total Alk. as $CaCO_3$	284	255	265	285	277	270	270	276	283	272	-	-
BOD, mg/1	32	33	21	21	11	13	3.5	8	6	-	25	23
COD, mg/1	105	85	135	160	75	22	8.0	95	47	95	77	79
Cond., umhos/cm	1285	1225	1260	1310	1165	1180	1230	1220	1300	1170	1160	1160
Chlorides, mg/1	143	134	137	135	122	118	119	145	-	-	128	115
Tot. Diss. Sol., mg/1	710	720	665	740	650	670	645	710	695	750	690	660
Susp. Sol., mg/1	30	340	220	475	100	-	65	35	16	60	28	23
Vol. Susp. Sol., mg/1	24	285	225	220	100	-	65	12	13	-	28	23
Sett. Sol., mg/1	0.0	0.1-	0.1-	0.5	0.1-	0.1-	0.1-	0.1-	0.1	0.2	0.1-	0.1-
NO_3N, mg/1	0.20	0.12	0.14	0.13	0.31	0.12	0.15	0.10	0.40	0.15	0.0	0.0
Total N, mg/1	-	-	-	-	-	-	-	-	-	-	16.4	16.6
Total PO_4, mg/1	-	-	-	-	-	-	-	-	-	-	3.3	3.4
Sol. PO_4, mg/1	-	-	-	-	-	-	-	-	-	-	3.1	3.3
ABS, mg/1	1.8	2.7	2.7	2.6	1.9	2.0	1.8	2.1	2.7	-	2.2	3.1
Coliform/100 ml	30,000	81,000	32,000	42	2300	4100	5	10[2]	660	330	5900	1100

1 First readily noticeable algae
2 Station 511 has 2200 coliform
3 Stations 513 and 514 only
4 Station 514 only

TABLE XI

Barr Lake Water Quality, 10-Foot Depth
Mean of Stations 512-514

	1964									1965	
Constituent	3-26	4-23	5-11	5-20	6-4	6-18	7-1	7-16	8-6	4-29	5-6
Temp., °C	4.6	12.0	12.0	18.0	16.0	20.0	21.5	24.0	24.0	12.9	14.0
D.O., mg/1	0.0	0.0	0.0	0.2	0.4	12.4	1.2	0.2	1.7	0.0	0.0
pH	7.7	7.9	7.8	8.0	8.0	8.7	8.0	-	-	7.8	7.9
Total alk. as $CaCO_3$	300	280	290	280	272	268	276	-	-	-	-
BOD, mg/1	40	26	14	15	11	12	8	4	8	28	24
COD, mg/1	86	176	127	176	50	96	38	-	-	65	80
Cond., umhos/cm	1230	1235	1265	1320	1095	1155	1245	-	-	1125	1210
Chlorides, mg/1	142	134	137	136	120	113	-	-	-	115	116
Tot. Diss. Sol., mg/1	730	725	655	682	657	650	675	-	-	700	655
Susp. Sol., mg/1	26	280	12	140	150	35	9	-	-	30	22
Vol. Susp. Sol., mg/1	26	240	12	140	150	28	9	-	-	30	22
Sett. Sol., mg/1	0.0	0.1-	0.1-	0.1-	0.1-	0.1-	0.1-	-	-	0.1	0.1-
NO_3-N, mg/1	0.13	0.09	0.09	0.14	0.30	0.08	0.10	-	-	0.0	0.0
Total N, mg/1	-	-	-	-	-	-	-	-	-	16.2	-
Total PO_4, mg/1	-	-	-	-	-	-	-	-	-	3.4	3.4
Sol. PO_4, mg/1	-	-	-	-	-	-	-	-	-	3.3	3.4
ABS, mg/1	2.1	2.9	2.7	2.7	2.0	1.8	2.1	-	-	1.8	2.8

TABLE XII

Barr Lake Water Quality, 20-Foot Depth
Mean of Stations 513 and 514

	1964									1965	
Constituent	3-26	4-23	5-11	5-20	6-4	6-18	7-1	7-16[1]	8-6[1]	4-29	5-6
Temp., °C	4.5	12.0	12.3	15.8	16.8	20.0	20.7	22.0	23.5	13.0	14.0
D.O., mg/1	0.0	0.0	0.0	0.0	0.2	11.5	1.0	0.0	0.0	0.0	0.0
pH	-	-	-	-	-	-	-	-	-	7.8	8.0
Total alk. as $CaCO_3$	-	-	-	-	-	-	-	-	-	-	-
BOD, mg/1	40	27	14	14	12	6	5	3	10+	26	22
COD, mg/1	-	-	-	-	-	-	-	-	-	80	-
Cond., umhos/cm	-	-	-	-	-	-	-	-	-	1150	1240
Chlorides, mg/1	-	-	-	-	-	-	-	-	-	120	-
Tot. Diss. Sol., mg/1	-	-	-	-	-	-	-	-	-	690	-
Susp. Sol., mg/1	-	-	-	-	-	-	-	-	-	21	-
Vol. Susp. Sol., mg/1	-	-	-	-	-	-	-	-	-	20	-
Sett. Sol., mg/1	0.0	-	-	-	-	-	-	-	-	0.1-	-
NO_3-N, mg/1	-	-	-	-	-	-	-	-	-	0.0	-
Total N, mg/1	-	-	-	-	-	-	-	-	-	16.4	-
Total PO_4, mg/1	-	-	-	-	-	-	-	-	-	3.3	-
Sol. PO_4, mg/1	-	-	-	-	-	-	-	-	-	3.0	-

[1] Station 514 only

TABLE XIII

Barr Lake Water Quality, 30-Foot Depth
Station 514

Constituent	1964						1965	
	4-23	5-11	5-20	6-4	6-18	7-1	4-29	5-6
Temp., °C	-	13.0	14.3	16.0	20.0	20.0	13.0	13.5
D.O., mg/1	0.0	-	0.0	0.0	13.9	0.0	0.0	0.0
pH	7.9	7.8	7.8	8.0	8.4	8.1	7.8	8.0
Total alk. as $CaCO_3$	292	287	296	286	280	292	-	-
BOD, mg/1	22	13	16	9	11.0	-	31	24
COD, mg/1	129	150	121	10	8	0	128	78
Cond., umhos/cm	1310	1135	1315	1240	1220	1280	1190	1170
Chlorides, mg/1	138	136	134	126	119	-	130	116
Tot. Diss. Sol., mg/1	785	675	690	650	675	670	700	655
Susp. Sol., mg/1	32	22	220	130	-	14	190	28
Vol. Susp. Sol., mg/1	28	200	120	130	-	9	94	28
Sett. Sol., mg/1	0.1-	-	0.1-	0.1-	0.1-	0.1	2.0	0.1
NO_3-N, mg/1	0.15-	0.09	0.11	0.38	0.8	0.06	0.0	0.0
Total N, mg/1	-	-	-	-	-	-	17.5	17.0
Total PO_4, mg/1	-	-	-	-	-	-	3.3	3.4
Sol. PO_4, mg/1	-	-	-	-	-	-	3.2	3.4
ABS, mg/1	2.7	2.6	2.5	2.3	2.2	1.7	-	-
Coliform/100 ml	1100	-	1100	-	-	-	-	-

Barr Lake, Tables X-XIII: Mean values are shown in Tables X-XIII for the four lake stations. As the lake was drawn down during the summer, these four stations were gradually dewatered until only station 514 remained at the end of August 1964. Self-purification in the lake was very slow until the water warmed to about 15°C in the latter part of May 1964. This warming due to the added insolation production increased bacterial and phytoplankton activity. The quality of water being introduced to the lake also improved because of the increased flow in the South Platte River, Table III. In the latter part of May, photosynthetic production of oxygen exceeded the biochemical oxygen demand during daylight hours and dissolved oxygen was then found in the upper waters of the lake during the remainder of the summer sampling periods.

This dissolved oxygen probably did not persist in the upper waters throughout the night in May and perhaps into June because of the high BOD in the water and the lack of much dissolved oxygen in the deeper waters. Self-purification, with a reduction in BOD, was so rapid after the middle of June that dissolved oxygen probably persisted in the surface water throughout the night. Dissolved oxygen was found at the 20 and 30-foot depths only during June, perhaps because of unusual wind mixing and heavy algal activity at that time.

Other than a small temperature difference, the only apparent changes in water quality with depth in Barr Lake were caused by the phytoplankton, which produced some variations in pH, suspended solids and dissolved oxygen between the deeper and the surface waters. Total suspended and volatile suspended solids were usually about equal at all depths, indicating the high organic content of the suspended matter.

By the end of June 1964, self-purification had reduced the BOD of Barr Lake to a relatively low value and the coliform bacteria concentrations were similar to or lower than those normal to surface waters in a farming region. Other constituents were little changed in their passing through Barr Lake.

Anaerobic conditions persisted in Barr Lake into May of 1964 and were probably present again in October or November and beyond, when quantities of sewage-laden water were diverted into the lake and phytoplankton activity was reduced. Under usual present conditions, odors could be emitted, therefore, from Barr Lake after the ice melts until usually about the end of May, commencing again about October or November and lasting until the lake freezes.

Self-purification was more evident in Barr Lake in the spring of 1965 (April and May samples, Table X), because water had not been introduced to the lake since April 16. Dissolved oxygen was not present in the lake by May 6, 1965, however, and the lake had a pronounced odor of hydrogen sulfide in the immediate vicinity, but no complaints were received from the Brighton area.

Plankton: Plankton samples were collected in Barr Lake periodically from April through August of 1964 and examined at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio (8). These analyses may be summarized as follows:

1. Algae and other organisms that predominated were of the type usually associated with organically polluted waters.
2. Numbers of algae were lowest in early spring (about 10,000 per ml) when water temperatures were low and were maximum in May (about 800,000 per ml) when water temperatures had risen, solar radiation increased, and the food source was maximum. During June, July and August, the number of algal

organisms fluctuated between 15 and 45 thousand cells per milliliter.

3. The numbers of algae present in the surface waters of Barr Lake during all periods of observation (April 23 to August 6, 1964) were in sufficient quantity to be defined as a "nuisance" bloom, had the water been used for any purposes but irrigation.
4. Blue-green algae predominated in April and May while green algae were dominant in June, July and August.
5. The ability of Barr Lake to support this large algal mass is due to the heavy fertilization the lake receives from waste water discharges.

Bottom Organisms: Bottom organisms were non-existent in lake areas having no dissolved oxygen. Bloodworms (midge larvae hatched from eggs deposited by adult flying midges from other water bodies) became established in the shallower portions of the lake when dissolved oxygen became available in the late spring. Other bottom organisms such as leeches, snails and sludgeworms that are usually found in organically rich bottom deposits were not found in

Barr Lake. Mosquito larvae were observed in the surface waters near shore where vegetation provided some protection. The midge pupae, being less tolerant than the larvae, were found in the areas where the water depth was three feet or less.

It is probable that a mass emergence of adult midge flies from the sediments could produce pronounced nuisance conditions around the lake.

A reduction in the deposition of organics to the Barr Lake sediments could result in more midge flies because of more tolerant conditions or it could result in fewer midges because of the establishment of predators and competitors for food. The long period of zero dissolved oxygen in Barr Lake and lake drawdown now results in the destruction of bottom organisms between summer seasons. If this destruction ceases, other bottom organisms less tolerant of low oxygen levels may become established. It is probable that the numbers of midge flies will be reduced in the future.

(Table XV is as follows:)

TABLE XV

Bottom Deposit Solids

Time Collected	Location	Station	Ash Percent	Volatile Solids Percent
Spring, 1964	Barr Lake, 1/4 Point	511	49	51
Spring, 1964	Barr Lake, 1/2 Point	512	88	12
Spring, 1964	Barr Lake, 3/4 Point	513	89	11
Spring, 1964	Barr Lake, 4/4 Point	514	72	28
Late Summer, 1964	Barr Lake, 3/4 Point	513	79	21
Late Summer, 1964	Barr Lake, inlet	510	81	19
Late Summer, 1964	Barr Lake, shoreline[1]	-	99	1

[1] Sample collected on sandy bottom, away from sludge beds

General sludge deposit observations:

a. Burlington-O'Brian Canal: 6-14 inch deposit septic sludge on bottom for most canal length.

b. Lake bottom is sandy. Sludge deposits generally confined within the 5070 contour (550 acres) and range in depth from 0.5 - 6 inches.

Bottom Deposits (Table XV): Barr Lake has a sandy soil bottom most of which becomes exposed near the end of each irrigation season. Solids that settle to the lake bottom and subsequently become dewatered, mineralize by bacterial action, desiccate in the sun, and essentially lose their identity prior to refilling of the lake. Thus, sludge deposits on the lake bottom are largely confined to that area of the lake constituting the "dead water" pool which lies below the 5,070 foot contour (about 550 acres or 3,700 AC-FT). In this area the sludge depths range from a negligible amount to around four inches, a shallow organic sediment depth indeed for a lake. As represented in Table XV, these sludges average about 80 percent ash, which indicates them to be rather well digested and typical of natural eutrophic lake sediments.

Examination of the Burlington-O'Brian Canal bottom by Public Health Service personnel disclosed a septic sludge in the canal which extended into the Barr Lake inlet, varying from 6-14 inches in depth.

(Table XIV is as follows:)

TABLE XIV

Barr Lake Outlet Water Quality
Station 515

	1964					
Constituent	5-20	6-4	6-29	7-16	8-6	8-27
Temp., °C	16.3	15.0	20.0	25.0	23.5	18.0
D.O., mg/l	0.3	0.0	3.4	0.8	1.6	8.2
pH	7.9	7.9	8.4	8.4	8.0	9.0
Total alk. as $CaCO_3$	316	292	276	268	288	312
BOD, mg/l	13	6	8	4	19	37[1]
COD, mg/l	137	14	110	-	51	176
Cond., umhos/cm	1300	1210	1105	1220	1350	1220
Chlorides, mg/l	136	126	131	-	-	-
Tot. Diss. Sol., mg/l	670	-	700	685	710	825
Susp. Sol., mg/l	150	60	32	8	21	150
Vol. Susp. Sol., mg/l	130	60	21	8	15	-
Sett. Sol., mg/l	0.1-	0.1-	0.4	0.1-	0.1-	1.0
NO_3-N, mg/l	0.16	0.34	0.80	0.09	0.40	0.14
Total N, mg/l	-	-	-	-	-	-
Total PO_4, mg/l	-	-	-	-	-	-
Sol., PO_4, mg/l	-	-	-	-	-	-
ABS, mg/l	2.8	2.5	1.8	2.1	2.7	-
Coliform/100 ml	33	3300	460	12	460	700

[1] Estimated

Barr Lake Outlet, Station 515 (Table XIV): Samples collected from the lake outlet at its point of discharge into the Speer Canal were essentially the same as those samples collected from within the lake at station 514. Coliform bacterial values were low; nitrate values were relatively high for a surface water; and the BOD values, while much lower than the lake influent, were still high for a normal surface water. The high suspended solids values are probably largely due to plankton. Detergent concentrations were high enough in the turbulent lake discharge to send clouds of foam down the irrigation canals.

Biochemical Oxygen Demand Loading on Barr Lake: Tables V and VI present the mean monthly biochemical oxygen demand loadings on Barr Lake during the study period and probable mean monthly loadings during the period of 1953-63. The data used in constructing these tables was discussed in previous pages herein. BOD loadings are reported in monthly mean units of pounds of BOD per acre of prevailing water surface per day. These are 5-day 20°C BOD values. This unit of loading is used because it is the conventional unit used in waste stabilization ponds with which Barr Lake will be compared. A more appropriate unit for deeper bodies of water like Barr Lake may be lbs/acre-foot/day.

The probable calculated BOD loading on Barr Lake during the study period was zero in the no inflow months of July, August, September and February. In other months it ranged from a low of 0.8 to a high of 103 lbs/acre/day in May and December of 1964 respectively (see Table V). During the period of 1953 to 1963, the mean monthly probable loading (Table VI) ranged from a low of 4.9 to a high of 33.3 lbs/acre/day in July and October respectively.

These values are in general rather conservative if one were to compare Barr Lake with a waste stabilization pond (or lagoon)[1] operating as an aerobic, anaerobic, or facultative treatment device. Aerobic or facultative waste stabilization ponds are usually 2-5 feet deep and their treatment effectiveness as an aerobic unit is more a function of their surface area than their volume. Anaerobic ponds are usually somewhat deeper, say 5-8 feet. Aerobic pond units normally function without odors and with high (over 90 percent) BOD reductions with loadings under good conditions up to 60-70 pounds of BOD per acre per day, as widely reported in the literature. These units with the higher loadings are shallow, the water temperatures are relatively high, and are not subjected to prolonged periods of ice cover. Barr Lake is cold during the season when odors have been experienced; also, anaerobic water from the deeper portions is mixed into the upper portions producing a higher unit area oxygen demand. In the spring, because of its greater depth, Barr Lake will take longer to warm than would a shallower pond.

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[1] It should be clearly indicated that Barr Lake is much deeper, much larger, and is operated in a different fashion from the normal waste stabilization pond. There do exist similarities, however, and this comparison is the best possible with present available knowledge.

Studies were made of sewage stabilization ponds in the Dakotas by the North and South Dakota Departments of Health and the Public Health Service (9). Although the winter temperatures in the Dakotas are colder than those around Denver, the spring and autumn temperatures are similar and thus it might be useful to state the pond design criteria recommended for the Dakotas. Because of the climate, BOD loadings not to exceed 20 pounds per acre per day are recommended for the Dakotas. In the winter-spring transition period, the time from ice melt to the establishment of aerobic conditions and an absence of odor, varied from 3 days on a shallow pond with a BOD loading of 6 pounds per acre to 53 days with BOD loading of 28 pounds per acre per day. These Dakota ponds produced atmospheric odors generally only during the transition period from ice cover to a well established algal population.

It is true that the present BOD loading on Barr Lake per unit of lake volume is low as compared to the Dakota lagoons because of its relatively large depth. However, in the Dakota lagoons, wind mixing will mix the entire lagoon contents and thus assist in reaeration, bring algae into contact with light, and it will disperse the food among the organisms. In Barr Lake, wind mixing is usually confined to the upper layers of water and the anaerobic condition with its oxygen demand proceeds in the deeper waters essentially at all times. The period of transition in Barr Lake from ice cover to an odor-free water can be expected to take from 30-60 days under present conditions of BOD loading.

Other Waste Stabilization Pond Data: Stanley (10) reports that in Manitoba and Saskatchewan BOD loadings up to 50 pounds per acre per day are allowed. Higher loadings may be allowed in Alberta if treatment requirements are not stringent. The odor nuisances have not been great even when anaerobic conditions existed for some time in these ponds. Localized sludge deposits on the pond bottoms did not produce any significant odor problems. Lagoons in

Canada, according to Stanley, have generally caused less odor problems than the average sewage treatment plant. In Manitoba, ponds are now permitted within a few hundred feet of dwellings. Experience with anaerobic ponds in Alberta indicated that odor problems were not too significant. However, recommendations are that anaerobic ponds not be built near habitations.

Neel, et al. (11), in lagoon studies in warmer Missouri, found that about two weeks were required, with BOD loadings of 60 pounds per acre per day, to establish sufficient photosynthesis, after melting of the ice cover, to permit aerobic conditions. With BOD loadings of less than 20 pounds per acre, a fairly transparent ice, and little snow cover, there was sufficient photosynthesis to provide aerobic conditions under the low rate of bacterial metabolism. They recommend winter loadings of less than 20 pounds of BOD per acre and would even then anticipate zero oxygen levels under the ice and for a few days after the ice cover leaves. Some sulfide odor was reported after ice melt with loadings above 60 pounds and ice cover of over 30 days duration.

Mackenthun and McNabb (12) in a study of Wisconsin stabilization ponds report that odors were associated with prolonged anaerobic conditions. BOD loadings of less than 9 pounds per acre per day did not produce odors after removal of ice cover; loadings of 11 to 17 pounds produced detectable odors up to two weeks after departure of the ice cover; and up to four weeks of odors were detectable after ice melt with loadings of 22 to 26 pounds.

Bartsch (13) reports that ice cover from 9 to 27 inches can reduce light intensity from 75 to 99.5 percent and thus greatly impair the process of photosynthesis. In ice-covered ponds, the dissolved oxygen may disappear rapidly followed by hydrogen sulfide formation which is trapped under the ice.

Horning, et al (14), in a study of small waste stabilization ponds around Cincinnati, Ohio, loaded at rates of 59 to 132 pounds/acre/day in the winter, reported BOD reductions of 56-75 percent. Ice cover was present at times but did not persist long enough to produce odor problems, even though the ponds were entirely anaerobic for several days.

Summary-Present Condition of Barr Lake: Water quality conditions associated with Barr Lake may be summarized as follows:

M. A. Bauer

1. The South Platte River upstream from the Denver North Side Sewage Treatment Plant discharge is polluted from a number of sources. It is anticipated that the majority of these will be connected into the sanitary sewer system before the new Metro plant is placed in service. River pollution is particularly significant during periods of low stream flow, usually December through February. Because of adequate natural reaeration, dissolved oxygen depletion does not appear to be a problem upstream from the Denver sewage treatment plant. Barr Lake water quality in the future could be significantly influenced by a continued degradation of these upstream waters due to population and industrial expansion. There should be a continual surveillance of the South Platte River water quality.
2. The primary source of pollution in the South Platte River, and in Barr Lake, is the partially treated sewage discharge from the Denver North Side plant. Discharge of organics from this source is well beyond the assimilative capacity of the South Platte River by any standard of water pollution evaluation. It is particularly

severe during periods of low stream flow when the Denver effluent will exceed the natural stream flow in volume. It is during this period of low stream flow that a significant portion of the water is diverted for storage in Barr Lake.

3. Largely because of the Denver North Side treatment plant discharge of partially treated sewage, digester supernatant, and digesting sludge, the Burlington-O'Brian Canal becomes quickly devoid of dissolved oxygen below the intake and discharges a septic stream into Barr Lake at all times when this has been measured (see Table IX) and most probably at other times.

4. Barr Lake is filled primarily during the non-irrigation season in a normal year when a large portion of the filling water is sewage treatment plant effluent, water temperatures are low, and the biota are semi-dormant. After the ice leaves and the lake commences to warm in the spring, anaerobic bacterial action accelerates on the entrained organics and it is probable that increased quantities of hydrogen sulfide are then produced by sulfate reduction in this

M. A. Bauer

relatively high sulfate bearing water. Algal activity remains at a low level because of cold water temperatures and a lack of light penetration due to a relatively high concentration of suspended solids in Barr Lake. It is probable that odors may be concentrated and carried from the lake during this period when atmospheric inversions are present and there is a breeze off the lake.

With increasing water temperatures and water clarity resulting from microbiological action, algae begin to appear in large numbers and produce enough oxygen through photosynthesis to help maintain the surface waters of the lake in an aerobic or near aerobic condition during the late spring and the summer with an absence of odor. In the autumn, as water temperatures cool, with a nearly empty lake that is being refilled with heavily polluted water, there once more exists a condition for odor production until the water temperatures drop to the freezing level.

5. Sludge deposits in Barr Lake are minimal and of little overall significance. The sludge in

these deposits, when examined, was largely digested and normal for an eutrophic lake.

6. Barr Lake provides a rather effective purification system comparable in some respects with a waste stabilization pond.
7. A comparison of Barr Lake with waste stabilization ponds, or lagoons, indicates that the present rate of BOD loading to Barr Lake is usually within normal BOD loading rates for typical facultative lagoons. When compared with operating experiences and loading rates for lagoons in areas of winter ice cover, it is evident that under present conditions odor will probably develop over a period of 30-60 days after the ice cover has melted. Odors may also be present prior to ice cover in the autumn when BOD loading rates are frequently high.
8. From an esthetic standpoint, the appearance of Barr Lake is unacceptable. Also, the odors produced by Barr Lake have been intolerable at times. Odors in this area may also originate from a number of sources other than Barr Lake.

M. A. Bauer

CONDITIONS EXPECTED IN BARR LAKE AFTER COMPLETION OF METRO SEWAGE TREATMENT PLANT

After completion of the Metropolitan Denver Sewage Disposal District No. I (Metro) treatment plant in late 1966 or early 1967, the question must be answered on how this will affect water quality in Barr Lake. Will a general beneficial effect be noted immediately or will some time be required for the overall lake water quality to improve; and will this beneficial effect be sufficient to remove all possible odor problems within the near future after the plant is placed in operation. A positive answer cannot be given to these questions since there are many variables involved. The future magnitude can only be given a predicted value at this time, The future quality of water diverted into Barr Lake will depend upon the rate of natural stream flow, the quality of the South Platte River water diverted into the Burlington-O'Brian Canal, and the quantity and quality of Metro effluent pumped into the canal during different seasons. Sufficient data are available or can be estimated, however, to permit a qualified evaluation on this future water quality.

The following conditions are taken for this evaluation:

1. Continuous and effective operation of the various sewage treatment facilities.
2. A BOD reduction of 80-90 percent in the new Metro treatment facilities that will produce an effluent the BOD of which will have an average maximum value not to exceed 50 mg/1 [1] (Denver has a strong sewage). "Design Criteria and Loadings," calculated by the Denver Metro Engineers, show a total raw sewage BOD of 256,000 pounds per day (this has been revised by recent additions to 270,000) for a design flow averaging 117 mgd (6). From these figures, it can be calculated that the average raw sewage BOD used in the design criteria is 262 mg/1. Overall plant performance or effluent standards are not stipulated in these design criteria. The raw sewage BOD of 262 mg/1 is considered to be on the optimistic or low side.

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[1] 50 mg/1 is also the average maximum allowable BOD that can be discharged by State Health Department regulations and Colorado State law.

3. No sludge or ash discharged with the effluent.
4. That liquid emanating from the sludge dewatering or disposal operations will be returned to the plant influent or the aeration unit influent.
5. That Barr Lake will have been drawn down to its dead pool elevation in the first summer of full-scale Metro treatment plant operation.
6. That the pollution loading now carried by the South Platte River upstream from the Denver North Side treatment plant will be reduced by approximately 60 percent to where the mean stream 5-day 20°C BOD is about 6mg/1.
7. That the same quantity of sewage treatment plant effluent will continue to be diverted by pumping into the Burlington-O'Brian Canal as at present in the autumn, winter and spring, to satisfy existing water rights (see Table II). (It is probable that less Metro plant effluent will be pumped than is assumed herein.)
8. That the future mean biochemical oxygen demand loading on Barr Lake will be as shown in Table XVI. This is considered to be on the non-optimistic

side. With careful water control and good treatment plant operation, these values should be lower.

(Table XVI is as follows:)

TABLE XVI

Estimated Future[1] BOD Loading on Barr Lake

	Estimated BOD in Burlington-O'Brian Canal 5-day 20°C mg/l[2]	Thousand Pounds of 5-day 20°C BOD Added Daily to Barr Lake	BOD Added Daily to Barr Lake lbs/acre/day[3]
Jan.	32	13.2	9.8
Feb.	28	8.7	6.0
Mar.	23	5.3	3.4
Apr.	17	4.9	3.0
May	12	3.5	2.4
June	13	4.3	3.2
July	17	1.6	1.5
Aug.	18	1.4	2.2
Sept.	23	2.1	3.8
Oct.	25	7.1	9.9
Nov.	24	9.0	9.4
Dec.	28	11.4	9.9

[1] By future is meant following construction of the Metro STP.

[2] Calculated from values in Tables II and IV assuming a STP effluent BOD of 50 mg/l and a South Platte River BOD of 6 mg/l. Both of these values were held constant.

[3] Calculated using Barr Lake areas in Table IV.

Table XVI indicates that the mean BOD loading on Barr Lake will be reduced to about 30 percent of the previous rate of loading (see Table VI) after full-scale operation of the new Metro sewage treatment plant. During the months of April through August, when the South Platte River flow is normally high (Table II), it is rather probable that no effluent would have to be pumped to the Burlington-O'Brian Canal. This would be a definite factor in reducing the possibility of autumn odors in late October and November, but would have little, if any, influence on the possibility of odors following the ice melt in March or early April.

Precise calculations cannot be made on the treatment processes taking place in Barr Lake, such as those proposed by Hermann and Gloyna (15), Oswald and Gotaas (16), or Rich (17). This is because Barr Lake is not a shallow even-depth lagoon, well mixed periodically by the wind; because input BOD values are approximated; and because the inflow, outflow, and water depths vary widely from month to month. It is possible to estimate the atmospheric reaeration rate and the oxygen requirements in the lake following the ice break-up. It is then possible to estimate the time required to oxygenate the upper layer of lake water to the point where odors are no longer released.

During the normal period of ice cover, late November to about the end of March, the 5-day, 20°C BOD of water entering Barr Lake would average around 27 mg/l. Oxygen entering the lake by advection and photosynthesis would probably not meet this demand. 5-day 20°C BOD removals under anaerobic conditions (if these prevail) range widely in anaerobic lagoons depending upon the type of waste, detention period, pond depth, and photosynthesis taking place (9) (11) (12) (14) (18) (19). Percentage removal values may range from about 50 to 75 percent. Barr Lake contemporary data indicate a removal of 60-75 percent in this period.

Immediately following the future periods of ice cover in Barr Lake, we may then expect the lake water to still have a 5-day 20°C BOD of about 10 mg/l if anaerobic conditions persisted.

Thus, when the ice melts, it is probable that an anaerobic condition will have been present in Barr Lake for a sufficient length of time to have produced appreciable quantities of sulfides. The sulfides would continue to be liberated until aerobic conditions became established in the upper waterlayers during a portion of the daylight hours.

In this transition period, the water temperature would probably average around 4-5°C (the deeper, denser water at about 4°C would be mixed by wind action into the colder overlying water after the ice melt). At this temperature, the oxygen saturation deficiency to just maintain aerobic conditions would be about 11 mg/1 and there would exist conditions for a maximum rate of oxygen transfer at the air-water interface. The rate of this transfer would be dependent largely upon wind action and would probably not be very effective at depths over 5 feet. Using Imhoff and Fair's approximation (2) for atmospheric reaeration,

$R = 0.0271\ (20)\ d\ (D_o)$

R = reaeration in lbs/acre/day

d = basin depth in feet

D_o = mean daily saturation deficit

$R = 0.0271\ (20)\ 5\ (11) = 30$ lbs/acre/day

the maximum rate of oxygen transfer would be about 30 pounds per acre per day following the period of ice cover.

As previously indicated, the 5-day 20°C BOD of water entering Barr Lake at this time is estimated to be about 27 mg/1 with an inflow averaging 43-54 cfs, taken herein to be 50 cfs or 32 mgd. Using the Phelps-Streeter formulations with a deoxygenation constant of 0.1 at 20°C and 0.05 at 5°C, the ultimate first stage

20°C BOD of the influent water is calculated to be 38 mg/l, or 28 mg/l at 5°C. It should be noted that the ultimate BOD at 5°C is less than that at 20°C. The daily oxygen requirement of this water is calculated to be (28)(8.34)(32) = 7,450 pounds per day. In March the lake area should be about 1,575 acres (Table IV). Dividing 7,450 pounds of oxygen required per day by 1,575 acres, gives an oxygen demand on an areal basis of 4.75 (or about 5) pounds per acre per day for this inflow water.

Oswald (19) states that the maximum average oxygen saturation deficit to be permitted is 6 mg/l if odors are to be strictly avoided 24 hours per day. Based on an oxygen saturation level of 11 mg/l for the lake, a minimum of 5 mg/l would be required in the lake to prevent odors. At a net rate of oxygen transfer to the lake of 30-5 = 25 lbs/acre/day, 3-4 days would be required to introduce approximately 5 mg/l of oxygen into the upper five feet of the lake. The increasing oxygen content of the lake would reduce the rate of atmospheric reaeration and the lake would actually require a somewhat longer period for development of odor-free conditions.

From the foregoing it can be concluded that after the new Metro plant is in regular operation, Barr Lake will have water quality conditions conducive to odor production for a short period following the ice melt. This period may last for about one week or until photosynthesis is well established, which could require up to two to three weeks, as observed at other locations under similar conditions. One difficulty at present concerning the onset of photosynthesis is the unusually large amount of suspended matter in Barr Lake, originating apparently in a large degree from the discharge of sludge and other suspended material into the South Platte River. Cessation of these sludge discharges should provide better water clarity and a more rapid establishment of photosynthesis than in the past.

Bottom sludge deposits in Barr Lake are not extensive, the sludge is relatively well digested, and these deposits should not affect the overlying water quality any more than in a normal lake.

In the autumn, as water temperatures cool and stronger waste discharges are admitted to Barr Lake, there should not be a recurrence of odor conditions as in the past because of the lesser organic loading to be admitted to the lake and the greater water clarity. The lake will be entering this period with a much higher water quality than in the past, photosynthesis will have been established, and there will be no prolonged period an anaerobic condition before the ice forms.

Since Barr Lake is largely drained each year and because bottom deposits are not of any great significance, it should reach the conditions described above in the spring of the year succeeding completion of the Metro plant in late 1966 or early 1967.

A secondary cause of odor from Barr Lake could arise from the decay of large amounts of algae driven ashore by wind action. Increased water clarity in the future should produce greater algal blooms. Algal odors may also come from off the lake itself. These, however, should not be intense and may be controlled by practical measures.

MEASURES THAT MIGHT BE USED TO IMPROVE FUTURE BARR LAKE WATER QUALITY

If indeed Barr Lake does produce appreciable and prolonged odor nuisances in the spring of the year following completion of the new treatment plant, there are several things that might be done to alleviate the situation (see next section for additional discussion). The practical way to accomplish this is to lessen the organic load imposed on Barr Lake. This can be done by:

(1) pumping only a minimum of Metro effluent to the Burlington-O'Brian Canal; some changes in water releases from storage and water allocations might be necessary;

(2) by producing a high quality effluent from the Metro plant; with skilled and careful operation, this plant could effect a 90 percent BOD removal rather than the 80 percent assumed herein; and

(3) by collecting or providing additional treatment to wastes entering the South Platte River above the Burlington-O'Brian Canal diversion.

These latter two items should, of course, be done regardless of whether Barr Lake produces an odor problem. Continued development of the Denver area is going to impose increasing waste loads on the South Platte River and it will be necessary to effectively treat all waste discharge if the stream is to be maintained as anything but an open sewer. It should be pointed out that any odor problems that might emanate from Barr Lake originate from upstream pollution and not from the Farmer's Reservoir and Irrigation Company.

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INTERIM MEASURES FOR IMPROVING BARR LAKE WATER QUALITY

In the one-year period prior to completion of the Metro sewage treatment plant, there is little that can be done from a practicable standpoint in reducing odors that may come from Barr Lake. Barr Lake has been widely accused for causing intolerable odor problems in Brighton. There are also many other potential sources of odors around Brighton, such as the local irrigation ditches, the nearby feed lots, processing plants, and sewage disposal plants. One measure that should be taken at all times is the control of emergent littoral vegetation on the lake. This serves as a harborage for mosquito breeding, it lessens reaeration from wave action, and it provides for the accumulation of floating scum and algae that will produce odors on decay.

Odors from Barr Lake could be prevented or lessened by reducing the organic waste input to the lake or by introducing oxygen to the lake water. With a clean shoreline and dissolved oxygen in the lake water, odors would be absent. Chemical treatment to artificially introduce oxygen to the water (for a bacterial respiration oxygen source) through the use of sodium nitrate, or to arrest bacterial action through use of a bactericidal agent, would be extremely expensive and probably not very effective because of the difficulty involved in near continuous application to such a large body of water during the odorous periods and prior to ice melt.

Oxygen could be introduced to Barr Lake or the feeder canal through use of various aerating devices that provide water circulation as they introduce oxygen to the water. These aerating devices could be submerged perforated pipes or hoses carrying compressed air or they could be mechanical aerators operating from a float or platform. Based on work by Riddick (21), as much as 780 horsepower might be required on Barr Lake to operate these aerators for effective aeration. Other devices would require more or less power, depending upon the design. A conservative rule of thumb value used in aerated lagoons is 2 lbs. of 5-day 20°C BOD removed per horsepower hour or about 50 lbs./day. With a Barr Lake BOD loading of 18,000 lbs./day in March and about a 75 percent 5-day 20°C BOD reduction, 270 horsepower would be required in special lagoons. Additional horsepower would be required for the BOD exertion beyond the 5-day period.

Aerators installed in the lake would probably prevent the formation of ice cover in the deeper portions of the lake and thus permit reaeration and photosynthesis in this area if operated for most of the autumn, winter and spring. Aerators installed in the Burlington-O'Brian Canal itself would not reduce the BOD enough to have a significant effect on the stored lake water. Aerators in the lake might be considered at some future time if other measures of odor control are not successful. However, at this stage in the problem alleviation, it would require an unjustified expense and a considerable period of time to design and install these aerators.

Use of the Burlington-O'Brian Canal as a series of oxidation ponds with control devices would not be effective unless the channel were enlarged to provide a total detention period of at least 20-30 days in ponds having a depth of about four feet. With Barr Lake inflows of 50-80 cfs in the problem period, this would involve enormous pond acreages, say 800 acres at least. The algae and bacterial cells produced in the ponds would also have to be kept out of Barr Lake, a difficult task, for they themselves would exert an oxygen demand on Barr Lake. The ponds would also have to be kept free of ice in the winter period for effective operation.

Treatment of the canal water through installation of aerating devices would not be effective unless control were effected to where sludge could be generated, removed by sedimentation, and recycled back to the influent, as in the activated sludge process. Provision would have to be made for excess sludge disposal. This is controlled sewage treatment and it should be carried on at the sewage source. Short-period, simple aeration in the canal would have little beneficial effect in consideration of the long detention period provided by Barr Lake.

In the interim until the Metro plant is under operation, the advisable course of action is to operate existing treatment plants to the best of their ability, monitor the river for wanton waste discharges, cease the discharge of all sludge and other solids to the river, remove littoral vegetation from Barr Lake on a routine basis, and check on other possible sources of odors in the vicinity of Brighton that may be corrected through improved housekeeping.

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